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HERPETOLOGICA

Volume 7 1951 *

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CHARLES E. SHAW

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SYMPOSIUM*

A SNAKE DEN IN TOOELE COUNTY, UTAH

By Angus M. Woodbury et al. as follows:

Introduction—A Ten-Year Study . . . . . Angus M. Woodbury
Temperatures of Entrance and Emergence . . . . . Basil Vetas
Sex Ratios of the Winter Populations . . . . . Gordon Julian
Egg Production of the Great Basin Rattlesnake . Henry R. Glissmeyer
Growth and Age in Western Striped Racer and Great Basin Rattlesnake . . . F. LaMarr Heyrend and Anson Call
Color Analysis in the Great Basin Rattlesnake . . . Earl W. Smart
Effects of Venom Injections in Rattlesnakes . . Raymond T. Sanders

ACKNOWLEDGMENTS

Many people have played a part in the study of this snake den. It was discovered by Nathan Reiser and John D. Vasquez on April 9, 1940, when they stepped onto the cobblestones of the den and found themselves surrounded by rattling rattlesnakes. Since April 12, 1940, when this study was initiated, many names of students, friends and scientists who assisted in gathering or processing the snakes, appear in the field records. Prominent among early assistants were the names of two students, Henry W. Setzer and Robert C. Pendleton and two sons, Dixon and Walter Woodbury. It was Walter who took care of his father when the latter was bitten by one of the rattlesnakes (Utah Acad. Sci., Arts & Lett., 1944, 19:179-184).

During the intervening years, many students have been taken to the scene, many Boy Scouts and curious friends have visited the site and the students participating in the symposium have undertaken serious work as part of the project.

In the early years of the study, many of the field trips were made at my own expense. Later, assistance for travel was given by Dr. R. V. Chamberlin, head of the Biology Department, University of Utah, and still later, funds for both travel and equipment were made available from the University Research Fund. For all services rendered, I am deeply grateful.

Angus M. Woodbury

*Given at a meeting of the Herpetologists League, June 20, 1950, during the AAAS meetings at Salt Lake City, Utah.

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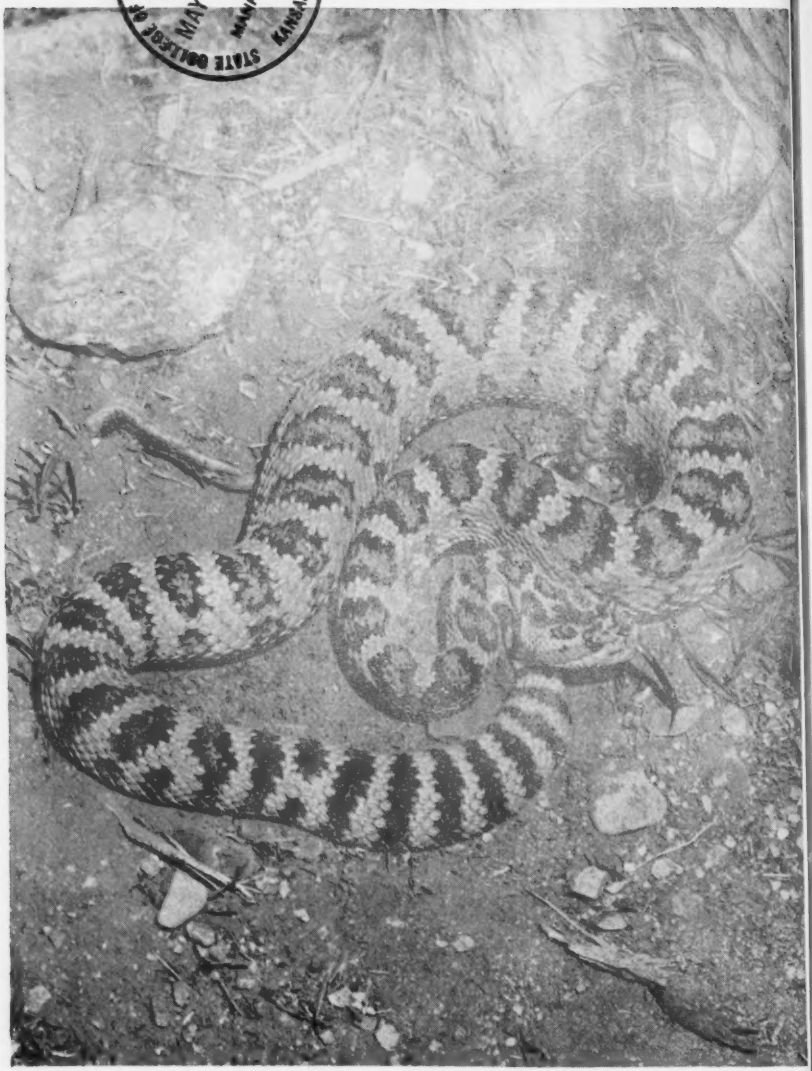

Figure 1. A view of a mature Great Basin rattlesnake showing the typical color pattern of the subspecies *C. v. lutosus*. Photo by Ray G. Jones.

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Dr. Angus Munn Woodbury

INTRODUCTION—A TEN-YEAR STUDY

Angus M. Woodbury

INTRODUCTION

It is well known that snakes regularly collect in specially favorable shelters called dens to avoid climatic extremes. This avoidance behavior pattern is a solution of only one aspect of the much larger problem that all animals face in trying to cope with the vagaries of their environment. If environmental conditions were always optimal and life could proceed without disturbance, there would be little need to develop such avoidance behavior but since environmental conditions do not remain placid and something is forever upsetting the equanimity of animals and subjecting them to conditions that may be described as suboptimal, uncomfortable, pessimal, dangerous or lethal, animals tend to develop characters that enable them to survive under unfavorable conditions.

Such characters may be morphological structures, physiological functions or behavior patterns that are perpetuated from generation to generation through the heredity mechanism. The behavior pattern which has primary emphasis in this paper, tends to guide the possessor instinctively to do the thing that racial experience has proved to be useful in perpetuation of the race. As a quail dashes for cover to escape a hawk soaring in the air, a rabbit goes foraging to assuage hunger, or gulls return to their nesting grounds before nest building time, so snakes return to their dens before the onset of climatic extremes.

In temperate regions, the critical climatic extreme is ordinarily represented by winter cold and snakes must ordinarily go underground to find conditions that permit them to survive the winter period without exposure to the disagreeable or lethal extremes. Such underground concentrations of snakes have been described by E. R. Hall (1929), H. K. Gloyd (1941), Paul Anderson (1947) and others. Robert Pendleton (1947) described a concentration or den of snakes in a tree trunk in the tropics where the snakes escaped heat extremes.

A winter concentration of frogs in the mud of non-freezing springs was reported by Lawrence Hope (1941). Winter concentrations of tortoises in long horizontal tunnels were described by Woodbury and Hardy (1948). The writer has been studying reptile dens since 1935.

Previous reports of dens have been concerned largely with numbers and kinds of snakes, times of concentration or emergence and the kinds of places where concentration occurs. Clifford Pope (1937), in reviewing the problem, referred to pilot black snakes, blue racers and bull snakes found together in a closed well; to 35 garter snakes in a muskrat burrow; to 3 species of snakes under a rotten stump; to 76 DeKay snakes in one place; to 10 garter snakes and one water snake in a rat burrow; to numerous DeKay snakes hibernating in ant hill tunnels; and to rattlesnakes and copperheads in crevices of rocky ledges.

Experience in hunting snake dens in Utah and western Colorado indicates that snakes do not make their own hibernating burrows but depend upon finding suitable places. They have been observed in loose cobblestone rocks, in gravel banks, in lava beds, in dry spring channels, in rock slides, in fallen clay banks, in deep rock crevices and in artificial hibernating places such as garbage dumps, rock walls and open house foundations.

Apparently there are no earmarks by which a snake den, *per se*, can be recognized. The best assurance is to find snakes entering or emerging. Sometimes cast skins of striped racers have been found around the den entrance but so far none of other species.

The fact of snake den concentrations had been well established by 1940 when after five years of miscellaneous study by the writer of snake dens in the intermountain west, a den suitable for a long-term study was located near Grantsville, Tooele County, Utah, about 40 miles west of the University of Utah Campus.

The den consists of a large number of loose cobblestones just below the shoreline of ancient Lake Bonneville where former springs had washed the loose material from among the stones and left underground channels into which the snakes descend for hibernation.

It is located on an easterly facing slope at the foot of the Stansbury Mountains bearing a heavy stand of sagebrush that is replaced about a mile down the slope by the salt-tolerant shadscale. This forms a belt below the sagebrush, and in turn yields to greasewood in the bottom of the valley. About a mile above the den, the sagebrush intermingles with the junipers and pinyon pines which extend upward into the mountains.

Since the den was discovered on April 9, 1940, snakes captured on repeated trips to the den during intervening years have been marked by tattooing a number on each snake to provide individual identification (Woodbury, 1948:127-8). In procuring these records, 151 fruitful trips were made to the den between April 12, 1940 and November 12, 1949, in addition to many trips on which no snakes were found.

From the den have come records of the Great Basin rattlesnake, *Crotalus viridis lutosus* (Fig. 1), the western striped racer, *Masticophis taeniatus taeniatus* (Fig. 2); mormon blue racer, *Coluber constrictor mormon;* the Great Basin gopher snake, *Pituophis catenifer deserticola;* the desert spotted night snake, *Hypsiglena ochrorhyncha deserticola;* the thimble snake, *Diadophis regalis regalis;* and the long-nosed snake, *Rhinocheilus lecontei.*

A total of 930 rattlesnakes, 632 striped racers, 127 blue racers, 36 gopher snakes, two spotted night snakes, two thimble snakes, and one long-nosed snake have been recorded and all but the last two tattooed. There have been in addition, 1080 recaptures of rattlesnakes, 443 striped racers, 28 blue racers, four gopher snakes and no recaptures of the thimble, spotted-night or long-nosed snakes. This makes a total of 2010 rattlesnake records and 1075 striped racer records, with a grand total from the den of 3285 of all snake records from 1940 to 1949 inclusive.

METHODS OF MARKING SNAKES

Two methods of marking snakes for individual identification have been proved useful. The method of clipping the ends of ventral plates in various combinations has the advantage of ease and convenience. The process requires only a pair of small scissors. Certain precautions are necessary for accuracy. Ordinarily, the anal plate is used as the starting point. By clipping ends of successive plates in successive snakes on right or left sides and then making various combinations on either one or both sides, a large number of snakes can be individually marked. There is always danger of error, however, in counting scales for identification upon recapture as well as danger of confusing right and left sides. A convenient way is to indicate the plates running forward from the anal plate by the letters of the alphabet and use a capital letter for the left end

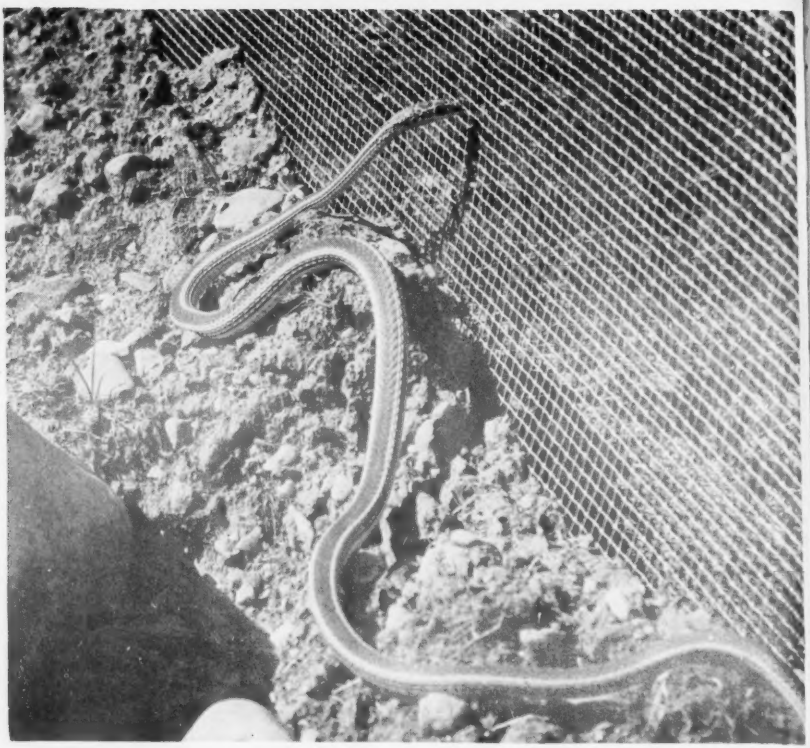

Figure 2. A view of a mature striped racer against the snake den fence. Photo by Joern Gerdts.

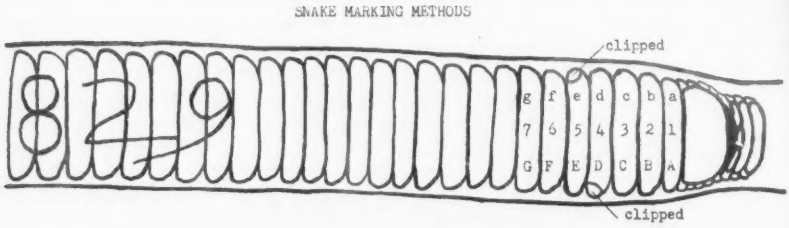

Figure 3. Sketch of abdomen of snake illustrating two methods of marking snakes for individual identification. The clipped ends represent snake indicated as De♀.

Figure 4. Processing a rattlesnake on the parking area adjacent to the snake den. F. LaMarr Hayrend and A. M. Woodbury.

(right side of snake) and a small letter for the right end (left side of snake) so that the snake can be designated by letters representing the plates clipped and the symbol for sex, thus DeF would indicate a female clipped on the left end of plate 4 and right end of plate 5 and bdM would indicate a male clipped on the right end of plates 2 and 4. (Fig. 3).

The other method consists of tattooing individual numbers on snakes. This requires a portable battery-operated tattoo outfit suitable for field work. The power must be sufficient to drive the needle through the scales. Numbers may be written on any smooth light-colored surface where no colored pigments interfere, such as the throat region or the base of the tail. Caution should be exercised to make figures as large as possible and make the free ends of such figures as 2, 3, 4, 6 and 9 as long as possible to aid in distinguishing them from each other and from the figure 8. Carelessness in making figures may lead to inaccuracies in identification but if once properly marked, the numbers serve as positive permanent identification.

PROCEDURES

This latter method was used in this study. The plan provided for taking samples from the den at every opportunity during entrance or emergence, marking them for individual identification, processing them to get specific information about each one; releasing them at or near the den and recapturing them from time to time to get more data. The data obtained from capturing and recapturing have led to the following possibilities for analysis:

1. Population estimates based upon the proportion of marked to unmarked snakes captured in the samples.
2. Composition of the population of the den, showing the sex ratios and age and size classes.
3. Life history data including egg production and biotic potential in some cases.
4. Growth data that enables calculation of length-growth rates and age-growth rates.
5. Times of entrance and emergence that permit calculation of hibernation and activity periods as well as analysis of differential emergence of sexes or juveniles.
6. Correlations between temperature, entrance and emergence.
7. Study of secondary sex characters.

Additional data taken with the aid of a color dictionary have made possible the analysis of the rattlesnake color pattern. The collection of venom has led to experimental study of the effect of venom injections upon the rattlesnakes themselves and could well lead to many lines of biochemical investigations.

In past years it has been the practice to make as many trips to the den as possible during the time when snakes were emerging in the spring or returning in the fall. Attempt was made on each trip to capture as many snakes as possible from the rocks and bushes. The maximum taken on any one trip was 91. During the last year of the study, the den was fenced and traps were installed in the fence (March 21, 1949). Hardware cloth two feet high and one-third inch mesh, at first used in the fence, was found to be ineffective in holding small snakes which crawled through the meshes and large ones that climbed over the top, hence screen wire cloth 30 inches high was substituted for the fall trapping period.

Captured snakes were placed in metal cages to facilitate handling while being processed. Most of the processing was done at a parking area adjacent to the den. (Fig. 4), but when time did not permit, they were taken to the university and usually returned to the den on the next trip. The processing included individual identification by tattoo number and two standard measurements, the snout-vent and total lengths. For rattlesnakes, additional data included tail-plate formula, rattle numbers and palpation of females to determine the number of eggs.

A field log was kept in duplicate by means of a carbon, in which information about field trips, snakes captured and processing data were recorded. Later, in the laboratory, these chronological data were transferred to systematic accounts, in which individual records of each snake were brought together for study.

These records serve as a foundation from which to analyze population data. In making such analyses, the rattlesnakes have been most emphasized, with striped racers second, because there is so much more information available for the former. They also occupy first and second place in total numbers inhabiting the den and thus yield larger samples for statistical study.

The samples taken by the fencing program are much nearer complete populations, and serve as controls from which comparisons can be made with the earlier samples. There are some difficulties, however, in making the comparisons. For example, the samples taken were not of uniform size and were not taken at comparable times; the den population is doubtless not stable from year to year due to addition of young ones, from death and probably from wintering elsewhere.

To assist in analyzing the populations, the new rattlesnakes taken and marked, each were studied separately and followed through succeeding years to get the records of their survival from year to year. They are listed in Table 1. The totals translated into percentages of survival in the samples taken were plotted on a graph shown in Fig. 5. This curve indicates a tremendous loss during the first year which seemed unreasonable as it was not supported by other data.

To check this, the newly marked rattlesnakes of each year were followed individually through successive years and the data are summarized in Table 2. The numbers first recaptured in successive years are shown on the top line of the table for each series. It is obvious that all of the first recaptures in successive years must have been alive in all preceding years even though they may not have been taken in the preceding samples. By adding these, the second line of figures in each series is developed to show all known survivors for each year. The totals are plotted on the curve shown in Fig. 5 and indicate a much smaller initial loss than shown by the samples.

This curve of the known survivors, however, is still far from accurate if the data from fencing be used as a criterion. Assuming that the results from fencing yield almost complete analyses of the 1948-49 and 1949-50 den populations, then a series showing percentage of survivors of each group as an average between the two winter populations gives an irregular curve, which, when plotted on Fig. 5, is still higher than the known survivors. If this irregular curve is smoothed, it then gives the best available indication of the survival rate of the general population.

It is well known that irregular sampling does not of itself yield satisfactory results in calculating population numbers. In this case, however, where sampling is combined with individual identification and liberal recapture records, a closer approach to accuracy seems to be possible in calculating winter den population numbers of the periods when samples were taken.

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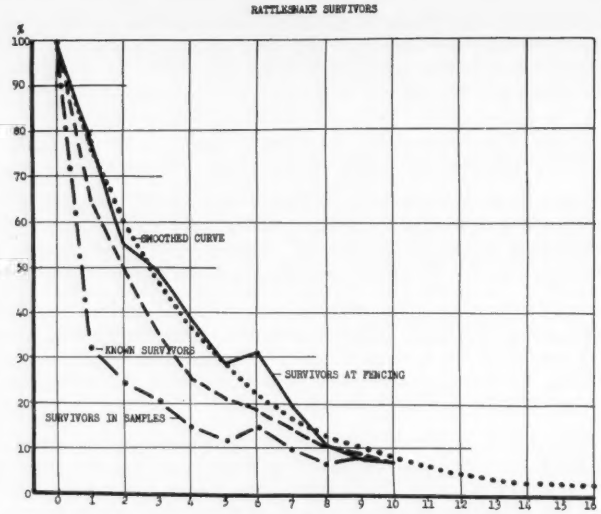

Figure 5. Graphs of annual survivors of marked rattlesnakes showing comparison of values of survivors in the samples, known survivors and actual survivors taken by fencing. The smoothed curve is projected into the future.

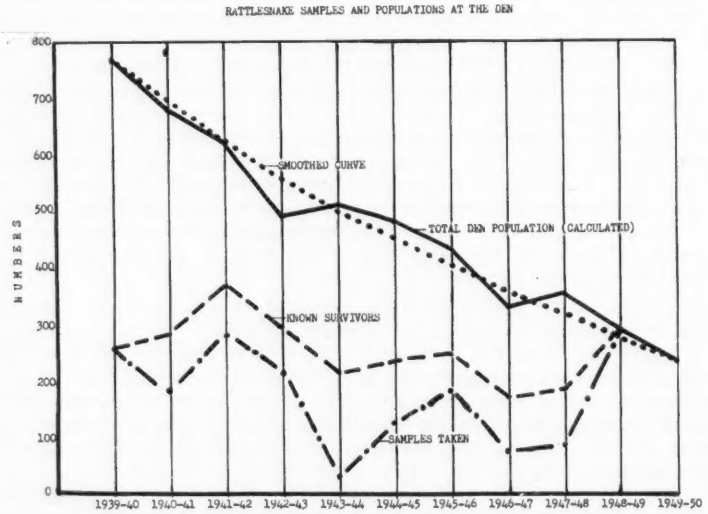

Figure 6. Graph showing numbers of rattlesnakes taken in samples, numbers of known survivors of marked snakes and the estimated den population from year to year.

TABLE 1
NUMBER OF SURVIVORS TAKEN
IN SAMPLES IN SUCCESSIVE YEARS AFTER MARKING

Winter den period	New Snakes	1	2	3	4	5	6	7	8	9	10 years
39-40	259	54	85	52	8	20	31	7	8	25	18
40-41	128	43	40	9	17	21	9	7	12	7	18
41-42	163	45	6	30	36	12	20	28	19	32	
42-43	77	8	13	23	8	9	25	19	39		1.9%
43-44	8	0	2	0	2	1	1	41		3.4%	
44-45	53	18	8	9	23	18	86		4.2%		
45-46	47	6	5	24	16	81		4.4%			
46-47	17	2	9	5	110		9.25%				
47-48	25	21	15	152		8.7%					
48-49	121	92	183		11.8%						
49-50	32	289		16.3%							
Totals	930		19.7%								
		31%									

TABLE 2
RATTLESNAKE SURVIVORS

	1940	40-41	41-42	42-43	43-44	44-45	45-46	46-47	47-48	48-49	49-50
		54	62	21	1	5	3	1	1	6	1
1940	259	156	124	70	43	42	40	28	27	26	18
			43	25	1	7	4	0	0	2	1
40-41		128	83	57	32	28	24	13	13	13	7
				45	4	17	11	2	6	7	2
41-42			163	94	74	63	53	37	34	30	18
					8	11	15	6	2	12	1
42-43				77	55	49	44	26	26	26	17
						0	2	0	1	0	0
43-44					8	3	3	1	1	1	1
							18	5	3	10	0
44-45						53	36	23	23	23	16
								6	5	19	2
45-46							47	32	26	26	15
									2	8	1
46-47								17	11	10	5
										21	1
47-48									25	22	13
											92
48-49										121	92
49-50											32
Den pop. (estimated)	769	679	622	492	514	480	437	331	356	297	235

The upper horizontal row of figures for each year shows the number of survivors first found (not previously recaptured) in each winter sample. The second rows show all known survivors in successive years after original marking.

Known Survivors of Successive Years

	0	1	2	3	4	5	6	7	8	9	10	
Nos.	898	584	379	264	189	146	114	88	58	33	18	total known survivors
%	100	64.9	42.1	29.4	21.0	16.2	12.6	9.8	6.4	3.7	2%	known survivors
%	100	82	55.4	42.3	37.6	30.2	33.7	20.2	10.5	8.5	7%	survivors determined by fencing.
%	100	78	61	48	38	30	23.5	17.5	13.5	10	7%	smoothed curve

The den population of the winter of 1939-40 may be calculated from the proportion *a divided by x equals a*1 *plus F divided by b*, in which, *a* represents the number captured and marked in 1940, *b* those of 1941, *x* the number not captured in 1940, *a*1 the number of *a* recaptured in 1941 and *F*, a factor of correction to compensate for losses from the population between 1940 and 1941. After solving *x*, the total popualtion may be calculated as *a plus x*. The correction factor *F* may be calculated from the smoothed curve of survivors in Fig. 5. It is realized that a correction factor should also be applied to *b*, but since data are not available to compute it, the factor is being ignored. It seems probable that since the increase will generally offset the losses in the unmarked population, the resulting inacuracy may be negligible.

Calculations for successive years become more complicated because each additional year brought more marked snakes into the population and each year brought successive losses from both the marked and unmarked portions as well as new additions by way of reproduction. A proportion for calculating the population of 1944-45 similar to that given for 1940 would be represented as follows: 30 *percent a plus* 38 *percent b plus* 48 *percent c plus* 61 *percent d plus* 78 *percent e plus* 100 *percent f divided by x equals a*6 *plus b*5 *plus c*4 *plus d*3 *plus e*2 *plus f*1 *plus F divided by g* in which *a, b, c, d, e, f,* represent successive captures of new snakes in successive years and the sub figures represent successive numbers of survivors in successive years. *F* is calculated for each of the latter by adding the calculated loss from each preceding year. Den populations of successive years calculated on this basis are shown in Table 2. These populations although probably not completely accurate represent the best available estimates from the data.

For further study, the numbers of rattlesnakes involved in the den studies are shown in a graph, Fig. 6. This shows on the lowest curve the numbers of snakes taken in the samples from year to year. The known survivors previously calculated on the basis that individual identification of each snake could be made, are shown in the middle curve of Fig. 6. The upper curve shows the total population of rattlesnakes as previously computed for each winter. This curve reveals with minor deviations a consistent decline in den populations for eleven winter den periods. The last two periods when nearly total populations were taken, fit very well into this general decline. The reasons for this decline have not been studied. The fact of decline is only now being established.

It is a moot question whether the den represents an isolated community or not. Searching for other dens within a 2-mile radius in the surrounding area has left the impression that this is the only one in that area. How far the snakes roam during the summer is unknown but one snake captured on the summer range was 1.25 miles from the den.

It is also unknown whether the snakes regularly return to the same den or whether there is mixing with other dens. The records have not been analyzed in detail in this respect but the indications are in general that the big majority of the marked snakes do return. Light was thrown upon the problem from an unexpected source. A summary of all measurement records from 1940 to 1948 was plotted to give a composite graph of the numbers of snakes of various body lengths, Fig. 7. This gives a curve with high peaks lying between 25 and 30 inches for females and 27 and 33 inches for males, with very low numbers of young snakes.

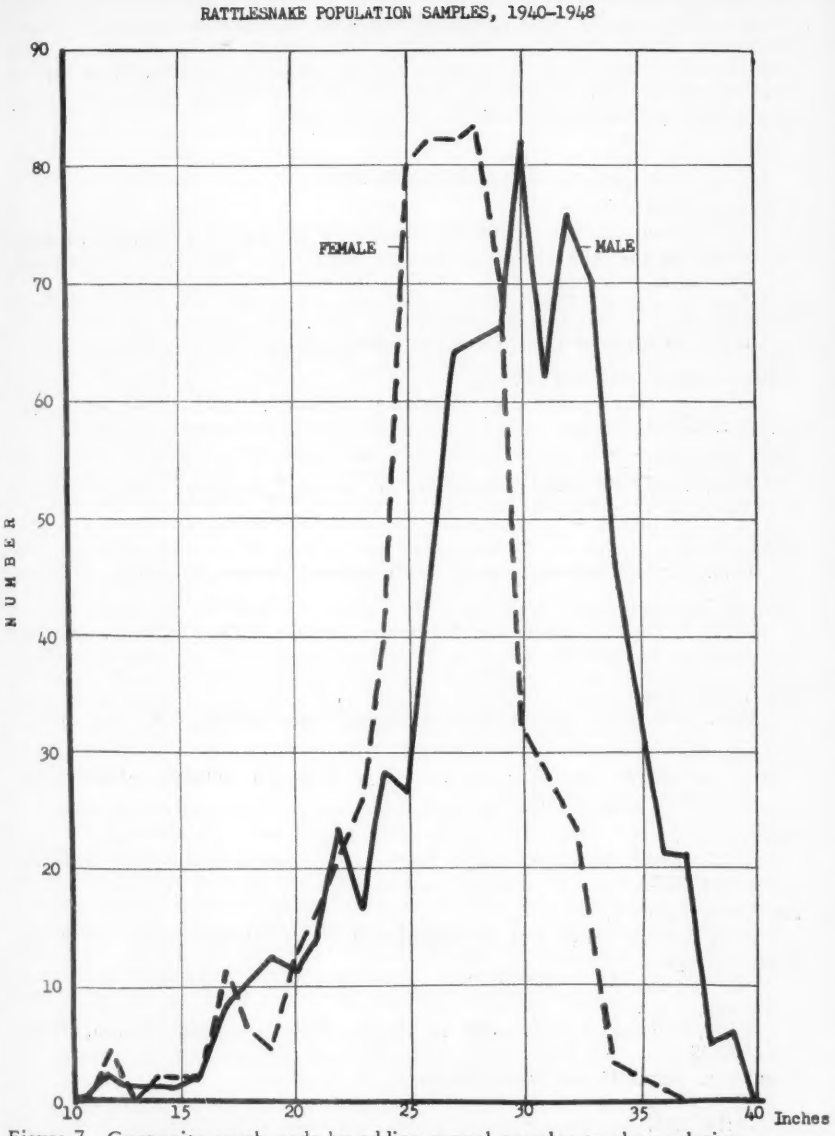

Figure 7. Composite graph made by adding annual samples to show relative numbers of snakes of given body lengths. Note the small numbers of young snakes and the high peaks following maturity.

This is a peculiar curve. If snakes continue to grow all of their lives, how can so many snakes of older ages be correlated with so few snakes of 1 to 3 years of age? There may be some compression of older age groups into length classes because of slower growth but that could not compensate for the difference. It is posisble that young snakes born on the summer range do not know their way to the den and only come to the den later in life as they mature when 3 or 4 years of age. They probably follow older experienced snakes.

REFERENCES

Anderson, Paul
1947. Observations on the denning habits of the prairie rattlesnake, *Crotalus viridis viridis* (Rafinesque). Chicago Acad. Sci., Nat. Hist. Miscellanea, No. 9:1-2.

Dargan, Lucas M. and Wm. H. Stickel
1949. An experiment with snake trapping. Copeia, 1949:264-268.

Fitch, Henry S. and Ben Glading
1947. A field study of a rattlesnake population. Calif. Fish and Game, 33:103-123.

Fitch, Henry S.
1949. Study of snake populations in central California. Amer. Midland Naturalist, 41:513-579.

Gloyd, H. K.
1946. Some rattlesnake dens of South Dakota. Chicago Naturalist, 9:87-97.

Hall, E. Raymond
1929. A den of rattlesnakes in eastern Nevada. Bull. Antivenin Inst. of America, 3(3):79-80.

Hope, Lawrence
1941. Life of the frog. Wisconsin Conservation Bulletin, 6:46-48.

Imler, R. H.
1945. Bullsnakes and their control on a Nebraska wildlife refuge. Jour. Wildlife Mgmt., 9:265-273.

Martin, P. J.
1930. Snake hunt nets large catch. Bull. Antivenin Ins. of America, 4(3):77-78.

Pendleton, Robert C.
1947. A snake "den" tree on Guadalcanal Island. Herpetologica, 3:189-190.

Pope, Clifford
1937. Snakes Alive. Viking Press, New York. 238 pp., 65 ills., 28 figs.

Woodbury, Angus M.
1948. Marking reptiles with an electric tattooing outfit. Copeia, 1948: 127-128.

Woodbury, Angus M. and Ross Hardy
1948. Studies of the desert tortoise, *Gopherus agassizii*, Ecol. Monographs, 18:145-200.
1950. Unusual snake records from Utah and Nevada. Herpetologica, 6:45-47.

Woodbury, Angus M. and Richard M. Hansen
1950. A snake den in Tintic Mountains, Utah. Herpetologica, 6:66-70.

TEMPERATURES OF ENTRANCE AND EMERGENCE

Basil Vetas

It has been well established that snakes of this western region enter the den in the fall, spend the winter underground and emerge in the spring. The problem of this paper is to determine the correlations between weather temperatures and the entrance and emergence of snakes from the den near Grantsville, Tooele County, Utah, as determined from the ten-year records indicated in a preceding paper.

Temperature records adjacent to the den were recorded on a thermograph for the spring emergence of 1949. Temperature records for other periods of entrance and emergence were obtained fom U. S. Weather Bureau records for Tooele, Utah, which station was adjudged to yield weather data very similar to that at the den. It is understood that snakes are probably affected more by ground temperature than by air temperature but since no ground temperatures are available and since there is a close correlation between the two except when the sun is shining on the ground, the air temperatures have been used.

Dates of entrance and emergence of the western striped racer, *Masticophis taeniatus taeniatus* and the Great Basin rattlesnake, *Crotalus viridis lutosus* were plotted on a graph, Fig. 8, to show the numbers emerging on given dates in comparison with the weather temperatures prevailing at the time. Temperatures are depicted on the graph by connecting the daily minima to make the lower line and the daily maxima to produce the upper line. This shows that during the period of emergence, temperatures ranged between 35 and 85 degrees F.

From studies of these and other data, it has been determined that the temperature of 60 degrees F. represents a close approximation to the threshold at which the snakes of the den tend to become active. This tentative figure, subject to future more accurate determination, has been used in this study. This threshold refers to air temperature that appears to stimulate snakes into activity, and not the snake temperature. When snakes first come to the surface, they feel cold to the hand and a few that have been measured yielded temperatures of 48 to 50 degrees F.

Snakes generally emerged from the den during the warmer parts of the day and were generally removed from the traps in early afternoon. Those that emerged in late afternoon were generally not counted until the next day, hence there was a slight lag between emergence and recording. Allowing for this lag, the correlation between emergence and weather becomes striking. In a general way, the higher the temperature above the assumed threshold, the greater was the emergence until the den was emptied. Whether this relationship is due to direct stimulation by warm air penetrating underground passageways or to accumulation of heat in the ground (temperature summation) was not determined.

The graph indicates that emergence of the striped racer, although similar in pattern proceeds earlier in the season and at slightly lower temperatures than that of the rattlesnake. Emergence of the mormon blue racer, *Coluber constrictor mormon* and the Great Basin gopher snake, *Pituophis catenifer deserticola*, which because of small numbers were not plotted on the graph, fell within the limits of those plotted. Totals of all snake emergence, if plotted, would yield a graph with sharper peaks and similar depressions, correlating with the high and low points of the irregular temperature cycle.

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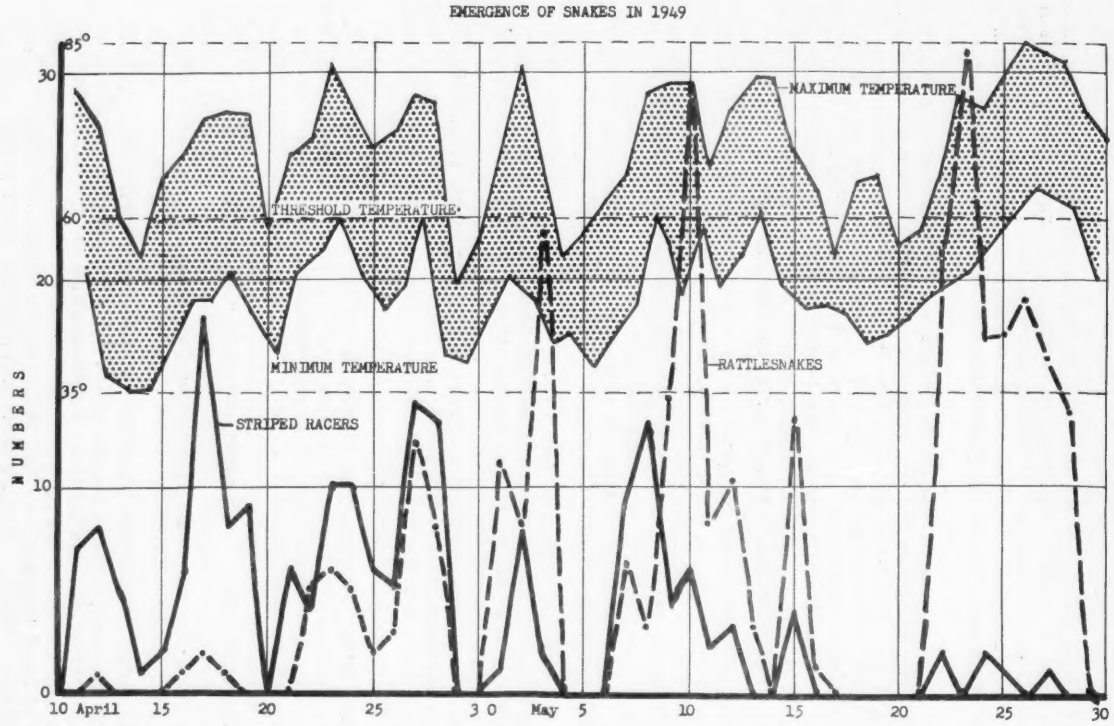

Figure 8. Graph showing emergence of striped racers and rattlesnakes on various dates in relation to temperature. The assumed threshold of activity is 60° F.

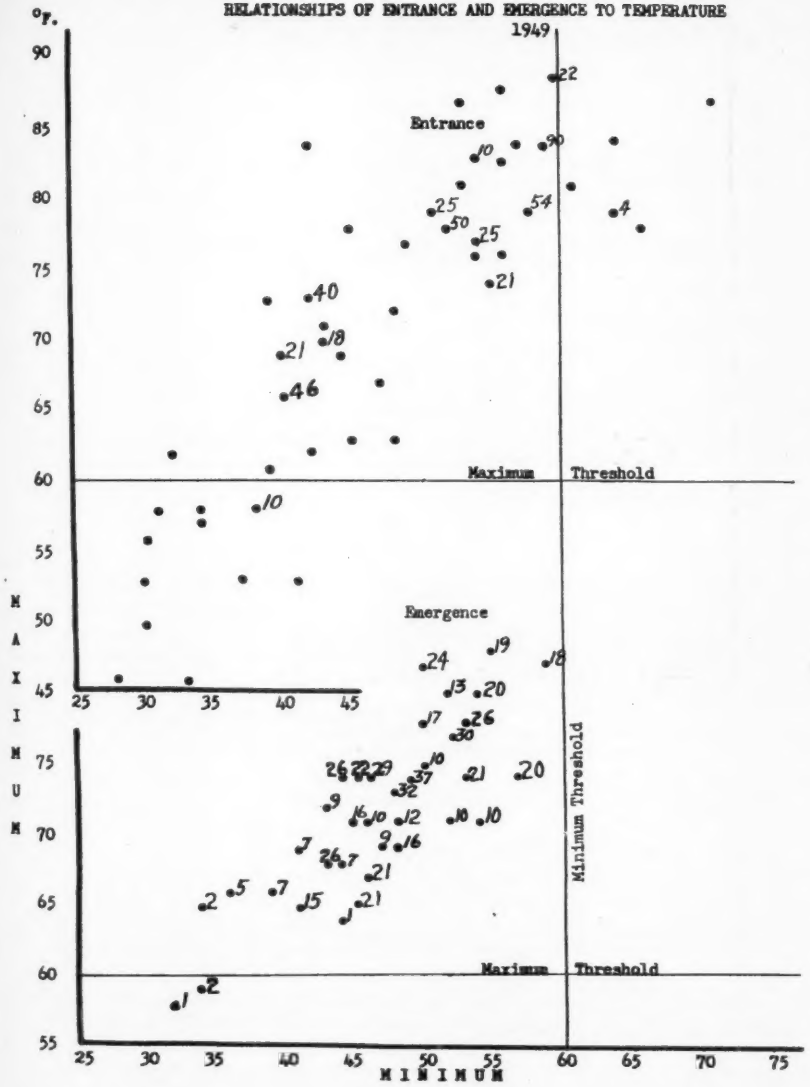

Figure 9. Scattergraphs plotted to show relationships between daily maximum and minimum temperatures and thresholds of entrance and emergence, 1949.

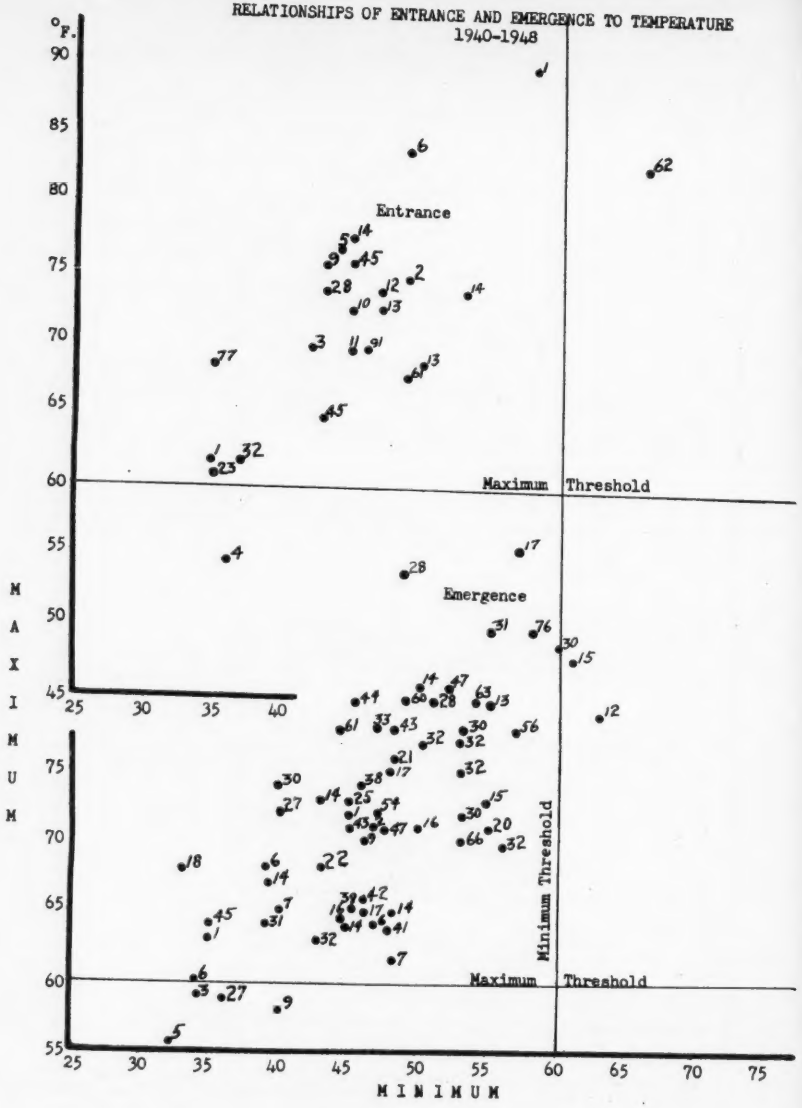

Figure 10. Scattergraphs plotted to show relationships between daily maximum and minimum temperatures and thresholds of entrance and emergence. Figures by the dots represent numbers of snakes, 1940-1948.

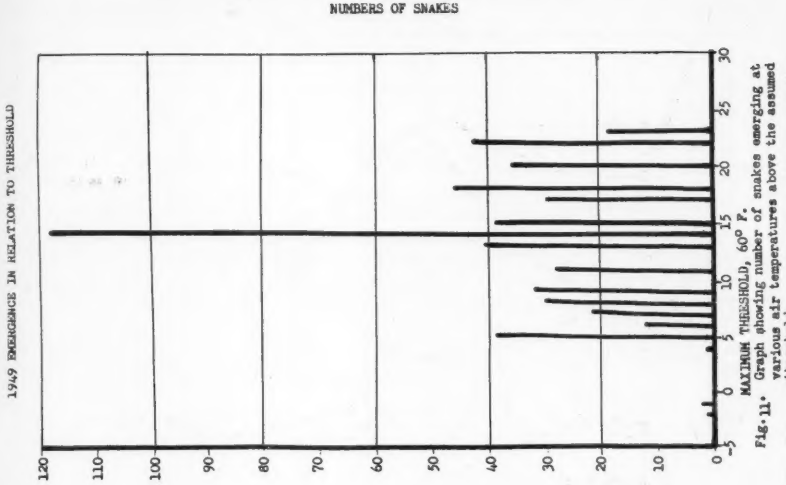

Fig. 11. Graph showing number of snakes emerging at various air temperatures above the assumed threshold.

In order to further investigate this relationship between temperature and snake activity in either entering or emerging from the den, scattergraphs, Figs. 9 and 10, employing coordinates of maximum temperatures on one arm and minimum temperatures on the other were plotted to show the numbers of snakes emerging under different temperature conditions. On the basis of the two graphs plotted, one for the year 1949 and one composite of the years 1940 to 1948 inclusive, it appears that emergence in spring is more closely confined and regulated by warm daytime temperatures than is entrance in the fall which is dispersed over a much wider range of daily temperature. Perhaps the internal drive that produces emergence is more definitely limited and consequently more snakes move in concert in the spring than in the fall.

From inspection of these graphs, the threshold of activity appeared to be approximately 60 degrees F. which coordinated closely with the practical experience over the years of sampling when it was learned that it was usually useless to go to the den unless the daily maximum temperature exceeded that figure. In order to test this further, a bar graph, Fig. 11, was plotted for the year 1949 to show total numbers of snakes emerging at various maximum temperatures above the assumed 60 degrees F. threshold.

This graph indicates that little activity occured in 1949 until air temperatures reached 5 degrees F. above the assumed threshold but the data from Figs. 9 and 10 indicate that considerable activity occurs when air temperatures are even below 60 degrees F. This figure appears to be a good compromise until further studies indicate further refinements and better understanding of the relationships of air temperatures to body temperatures of snakes.

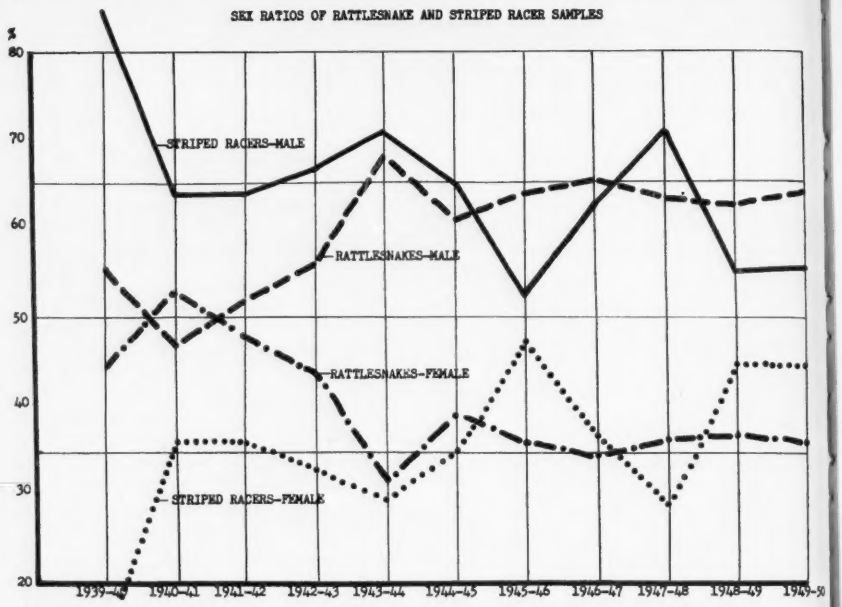

Figure 12. Graph showing sex ratios of samples taken in various years of rattlesnakes and striped racers.

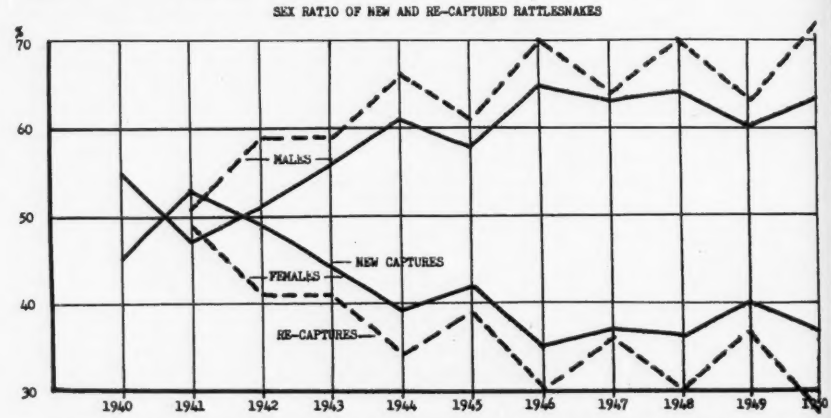

Figure 14. Graph showing sex ratio of newly captured rattlesnakes (solid line) and recaptures (broken line) from year to year. The difference may not be due to processing the snakes.

SEX RATIOS OF THE WINTER POPULATIONS

Gordon Julian

From the data accumulated at the snake den near Grantsville, in Tooele County, Utah, it became evident that there was a great preponderance of males over females in the populations of both rattlesnakes (*Crotalus viridis lutosus*) and striped racers (*Masticophis taeniatus taeniatus*). These differences persisted with only one exception year after year, at least through eleven winter seasons. It is the purpose of this paper to analyze these differences and attempt to account for them.

A tabulation of the total samples taken from each winter den population is given in Table 1. This shows that in only one year did the females exceed the males in the rattlesnake samples but there was no such exception among the racers. When plotted on a graph as shown in Fig. 12, they make irregular curves but when the yearly totals are added, they yield a cumulative total for rattlesnakes of 59.5 per cent males, 40.5 per cent females and for striped racers of 62 per cent males and 38 per cent females. This raised the question whether there was a genetic difference in sex ratio at time of fertilization or whether there was a differential ratio of survival at a later time in life.

No convenient method was available for testing the sex ratio of the zygotes but data were available from which the ratio of hatchlings could be compared with that of older snakes. The records that had accumulated from the method of marking snakes individually for identification contained many records of individual snakes in which not only initial ages were known but later ages were also known from recapture records. When the numbers of each sex in this group were plotted against the number of rattles they bore, it made a curve shown in Fig. 13.

These were all young snakes ranging from hatchlings to 7 or 8 years of age and did not include older snakes whose initial ages could not be determined. The curve appears to be significant in showing that the sexes are about in equal proportions in the first three years of life but the ratios begin to diverge thereafter at about the time of sexual maturity. This suggests that the divergence is due to differential survival rates of the two sexes after sexual maturity.

In the course of calculating the various winter populations, the new snakes found each year were plotted against their survivors taken in later samples. When plotted as shown in Fig. 14 for rattlesnakes, it was discovered that there was a consistent difference in the sex ratio in which the males showed a greater preponderance in the recaptures than among the new snakes when first captured. This raised the question whether handling and processing of the snakes might be harder on the females than the males or whether the males might live longer than females.

In order to test the first hypothesis, the snakes were sorted into series of successive recaptures so that sex ratios of first, second, third andfourth recaptures could be compared with each other and with the first capture. A summary of this study is shown in Fig. 15. This indicates that there is a successive divergence and greater preponderance of males in successive recaptures but handling of the snakes may not be the proper answer as will be shown later.

In order to test the idea of greater male survivorship, the new rattlesnakes marked each year were followed through successive years and the sex ratios were listed in Table 2. The summaries from this table show a gradually diverging sex ratio in which the males assume a gradually increasing preponderance. When translated to percentage and plotted on a graph, the irregular curves of Fig. 16

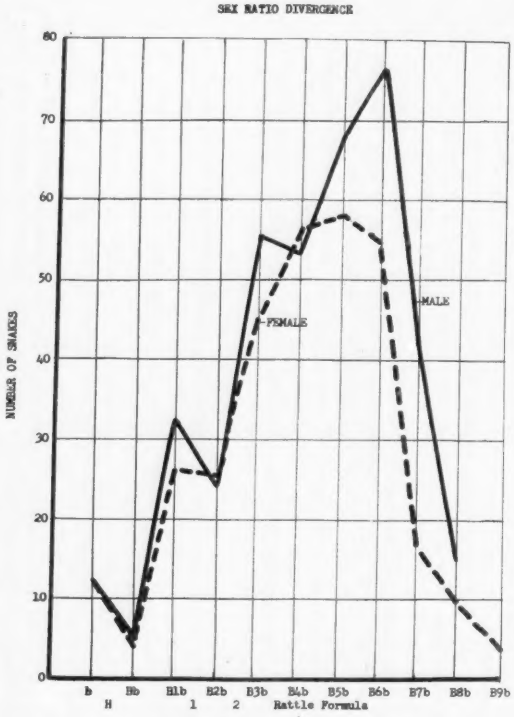

Fig13. Graph showing numbers of snakes with given rattle formula in the two sexes.

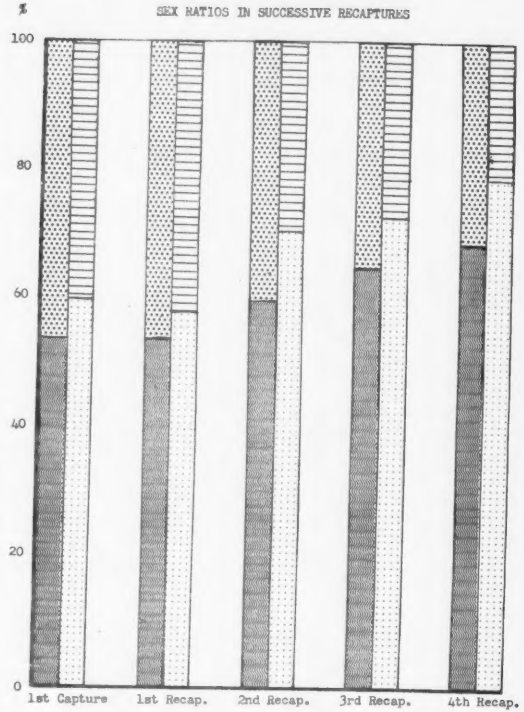

Fig. 15 Graph showing the sex ratio in successive recaptures for 1940-48 in left column and 1949 in right column. Males below; females above.

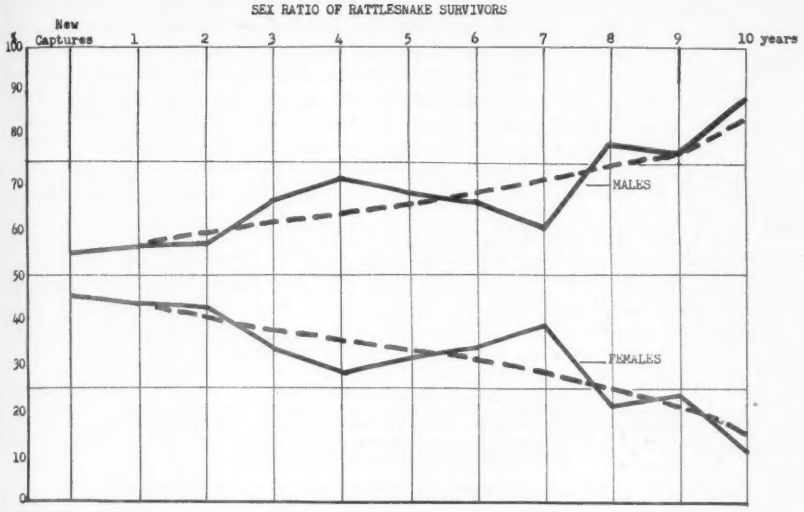

Figure 16. Graph showing sex ratio of rattlesnake survivors in samples taken from year to year (solid line). The smoothed curve (broken line) indicates a general trend of females dropping out of the population faster than the males.

TABLE 2

	Captures		1 yr.		2 yr.		3 yr.		4 yr.		5 yr.		6 yr.		7 yr.		8 yr.		9 yr.		10 yr.	
	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F
39-40	143	116	27	27	45	34	35	17	5	0	10	8	16	10	3	4	6	0	16	7	16	2
40-41	58	68	20	21	20	20	4	5	13	4	12	9	7	2	5	3	7	5	7	0	16	2
41-42	82	81	21	24	4	1	14	14	20	16	9	2	11	8	15	10	16	3	23	7	88.9	11.1
42-43	43	34	4	3	9	4	15	8	6	2	6	3	17	7	14	5	29	8	76.7	23.3		
43-44	4	4	0	0	2	0	0	0	2	0	1	0	1	0	37	22	78.4	21.6				
44-45	31	22	13	5	3	5	7	2	17	6	15	3	52	27	62.7	37.3						
45-46	30	17	5	1	2	3	16	7	13	3	33	23	65.8	34.2								
46-47	10	7	2	0	5	4	15	0	76	31	67.9	32.1										
47-48	12	13	10	11	8	6	106	55	71.0	29.0												
48-49	73	48	56	35	98	77	66.7	33.3														
49-50	24	12	158	127	56.0	44.0																
Totals	510	422	56.4	43.6																		
%	54.7	45.3																				

TABLE 1

SEX RATIO OF SNAKES HANDLED FOR EACH WINTER DEN PERIOD

Winter Den Period	Rattlesnakes		Striped Racers	
	M	F	M	F
1939-40	143	116	51	9
1940-41	85	95	60	33
1941-42	155	143	78	44
1942-43	121	94	55	27
1943-44	26	12	12	5
1944-45	81	52	68	36
1945-46	116	65	64	56
1946-47	44	23	46	26
1947-48	56	32	20	8
1948-49	184	107	97	76
1949-50	168	64	103	82
Totals	1179	803	654	402
	59.5%	40.5%	62%	38%

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are produced. Smoothed curves by the graphic method make the trend clear.

It seems evident, therefore, that the females drop out of the population faster than the males. This seems to mean that the males live longer than the females. If so, this could account for the general sex ratio as well as the differences in the ratios of successive recaptures. It would, therefore, not be necessary to assume that handling and processing was harder on one sex than the other. The longer life span of males could account for the differences. This possible conclusion is further corroborated from the data given in the first paper which showed a steady decline in the den populations approximately of the same order of magnitude in years when only a small sample was taken as when the total population was affected by fencing.

The trend thus revealed in the rattlesnakes seems to apply to the striped racers although the data have not yet been tabulated and analyzed. The conditions are so parallel and the trends so nearly alike that it is assumed the divergence in sex ratio in the racers stems from the same cause—a longer life span in males. The totals over the years indicate a greater and more consistent divergence in the sex ratios in the racers that were not palpated than in rattlesnakes that were.

EGG PRODUCTION OF THE GREAT BASIN RATTLESNAKE

Henry R. Glissmeyer

The problem to be presented in this paper is that of egg production in the Great Basin Rattlesnake, *Crotalus viridis lutosus,* and is therefore primarily concerned with the females but since eggs are the source from which all members of the population are derived, it follows that the relationships of eggs to the perpetuation of the population must be explored.

During studies of eleven successive winter den populations of the snake den near Grantsville in Tooele County, Utah from 1940 to 1950 inclusive, many of the female rattlesnakes were palpated to see if they were bearing large eggs. Palpation was useless in other species because of the difference in the egg development cycles. It is probable that the striped racer, the blue racer and the gopher snake have annual cycles of egg development in which certain small eggs of the ovary begin to enlarge soon after the snakes emerge from hibernation in April or May, continue their development by early summer and enter the oviduct where they are fertilized and where the eggs are completed by the addition of the white and the leathery shell. After depositing the eggs in early or mid summer, the females return to the den in the fall without any enlarged eggs.

This is in contrast with the rattlesnakes which appear to have a biennial cycle in which the females return to the den one fall with enlarged eggs and the next year without them. This can be explained by the hypothesis that a few small eggs of the ovary begin to enlarge in late summer and complete about two-thirds or three-quarters of their development by the time they enter the den in the fall.

Egg development is probably completed soon after emergence in April or May and the eggs probably pass into the oviduct about May or June. After fertilization and completion, they are retained in the oviduct during development of the embryos and discharged sometime about August or September. The snakes then have no large eggs when they return to the den in the fall. Occasionally the young are presumably born at the den. By careful palpation, eggs in the oviduct can usually be distinguished from those in the ovary.

Palpation was accomplished by pressing the thumb along the abdomen to detect the presence of eggs. If large ones were found, then two thumbs were brought into play and each egg was successively held between them for counting. At first, the gravid and non-gravid condition was indicated in the record, but later the actual number of eggs counted was entered so that it was possible to calculate total numbers of gravid snakes and total numbers of eggs produced by them. From other data, it became possible to estimate the total den populations from winter to winter and derive total egg producion for each succeeding summer.

It became easy to recognize gravid snakes but in some cases it was difficult to separate immature snakes from the mature non-gravid females. In order to ascertain how to distinguish these, a scattergraph shown in Figure 17, was plotted with rattle formula against body length to show when young females first became gravid. Assuming that the rattle formula B4b represents an age of at least three years, it is obvious that snakes become gravid at three or four years of age and mainly when they are about 25 inches in length, although exceptions extend down to 22.2 inches and up to 27.3 inches.

After segregation of the immature snakes, the data from adult females were used to prepare Table 1 which shows the number of gravid females in the annual samples, the number of eggs produced in the samples counted and the total egg production of the entire winter colony. This total for each winter may be regarded as the potential egg crop for each following summer.

The tabulation shows that the average of gravid females varies from 4.2 to 6.6 eggs with an overall average of 5.5 for all gravid females that were palpated. These are averages, however, and the range of egg numbers varied in different females from 2 to 9.

The percentage of gravid females among the mature females of the den varies a great deal from year to year, 12.5 to 66.7 per cent, but the general average for the eleven season period is 49 per cent which tends to corroborate the hypothesis of a biennial cycle in the rattlesnakes. The numbers of gravid females in the den populations from year to year, the percentage they represent of the total mature females and the ratio in percentage of the total eggs to the total population are plotted in Figure 18.

The resulting curves are very irregular. The sharp dip in two of the curves in 1943-44 may be due to the smallness of the samples taken that year but that cannot explain the low dip in 1949-50 in which the sample represented almost the entire population. The record is not long enough to delineate long time trends but theoretically, if these females follow a biennial cycle, it would be expected that the percentage curve of gravid females would continually oscillate above and below the 50 per cent line in alternate years.

The plotted curve does not follow this pattern. The four points on the curve from 1945-46 to 1948-49 are all above the 50 per cent line. How this could happen in four successive years is not explainable on the biennial hypothesis unless the samples of those years are not representative of the real conditions of the population or unless the population changes from year to year by additions or losses to other areas.

LITERATURE

Klauber, L. M. 1936. A statistical study of the rattlesnake. Occ. Pap. San Diego Soc. Nat. Hist., 1:2-24.

Rahn, Herman. 1942. The reproductive cycle in the prairie rattler. Copeia, 1942: 233-240.

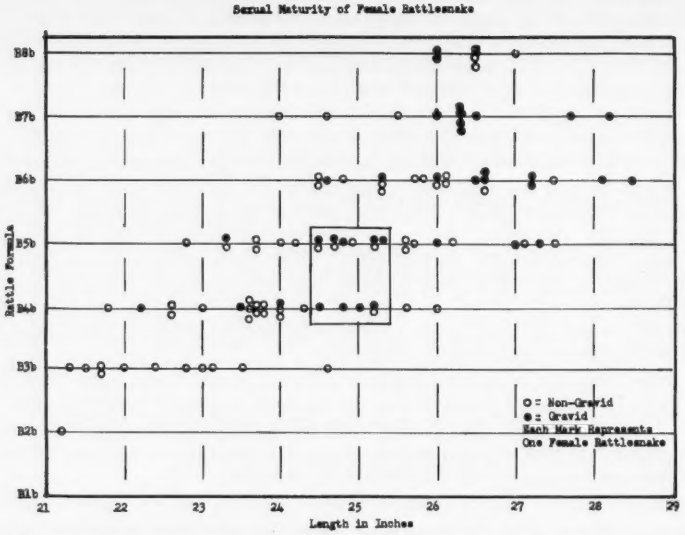

Figure 17. Scattergraph, with length plotted against Rattle Formula to locate area of sexual maturity.

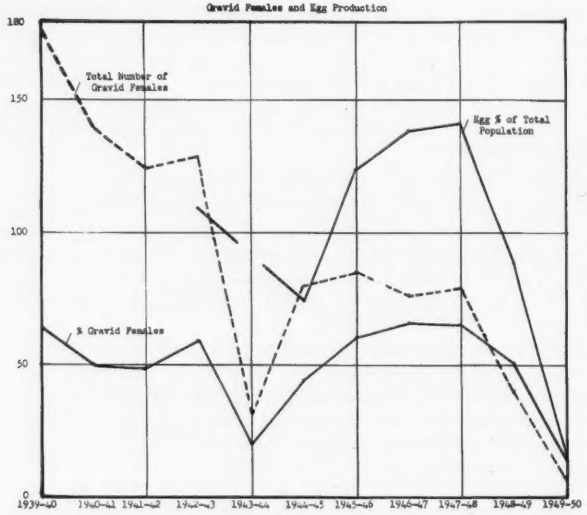

Figure 18. Graph showing total numbers of gravid females in the den from year to year, their percentage of the total female population and the eggs they produce.

Table 1

Samples of Females and Estimated Totals of Den Population

	Samples Taken						Den Totals (estimated)				
	Total Adult Females	Total Nos. Palpated	Gravid		Total Eggs	Ave. Eggs per Females	Total Pop.	Total Adult Females	Total Gravid Females	Total Eggs	
			Nos.	%						Nos.	% of Pop.
1939-40	99	55	35	63.0			769	294	176		
1940-41	74	68	34	50.0			679	279	140		
1941-42	123	84	41	48.8			622	257	125		
1942-43	95	78	46	58.9	194	4.2	492	217	128	537	109
1943-44	12	5	1	20.0			514	162	32		
1944-45	50	32	14	43.8	63	4.5	480	180	79	356	74
1945-46	59	52	31	59.6	201	6.5	437	143	85	553	126
1946-47	23	21	14	66.7	85	6.0	331	114	76	456	138
1947-48	30	26	9	34.6	58	6.4	356	121	79	507	142
1948-49	78	55	28	51.0	185	6.6	297	78	40	264	89
1949-50	48	47	6	12.5	31	5.1	254	48	7	36	13

5.5 Average

GROWTH AND AGE IN WESTERN STRIPED RACER AND GREAT BASIN RATTLESNAKE

F. LaMarr Heyrend and Anson Call

INTRODUCTION

The purpose of this study is to establish the age and growth relationships of the western striped racer, *Masticophis taeniatus taentiatus,* and the Great Basin rattlesnake, *Crotalus viridis lutosus* from data accumulated during the ten- year study of the snake den near Grantsville, Tooele County, Utah. Data from the field notes which gave two standard measurements, snout-vent length and total length as well as rattle counts, were transferred to systematic accounts, in which individual records of each snake were brought together for study. From the systematic accounts, after careful checking, tables were compiled to show: (1) the difference in length of individual snakes at successive recaptures, and (2) in rattlesnakes, differences in rattle numbers at successive recaptures. From these tables, other tables and graphs were compiled to show age, length and rattle relationships.

From the large number of records, it appeared that little, if any, growth took place during hibernation. Since our measurements were taken at the beginning or end of the active summer growing season, we have used the growing season as a unit for measurement. In all cases it is the snout-vent measurements (head and body length) that are used, not total length. In all tables, the data are given for each sex of each species separately.

REFERENCES IN LITERATURE

A very general review of literature dealing with age and growth was given by Pope (1937:26-34). About the same time, Klauber (1937:1-56) published his detailed analysis of the growth of rattlesnakes. Growth in the fence lizard in Oregon was studied by Fitch (1940:151-172). A parallel study of growth in the blue-tailed skink in California was made by Rodgers and Memmler (1943:63-67).

Measurements of a population of gopher tortoises in Florida by Goin and Goff (1941:66-68) showed that 33 tortoises increased an average of 11.5 mm. in length in approximately one year. The studies of Woodbury and Hardy (1948: 167) in southwestern Utah indicated that the desert tortoise with its exceedingly long life reaches an adult stage where growth is much reduced and probably stops entirely. The studies of snakes reported in this paper are in general agreement with findings in other species of reptiles that there is a rapid growth rate in hatchlings which gradually slows down as they get older but there is no evidence that a stable adult size is reached as shown for the desert tortoise. We are indebted to Dr. Lowell A. Woodbury for assistance in the statistical analysis.

LENGTH-GROWTH RELATIONSHIPS

From the inlividual snake records of the systematic accounts, tables were prepared showing for each inch-length class, those cases in which two measurements showed a lapse of one growing season. A summary of these tables showing the average and percentage increase in length is given in Table 1 for rattlesnakes

and in Table 2 for striped racers.

From Tables 1 and 2, the data were plotted on graphs, body length against measured increase and against percent increase for each sex of each species. After the coordinates were determined from the summary tables, they were plotted on semi-log paper, from which a straight line whose formula was computable was derived. From this, a smoothed curve was developed which was plotted for comparison with the graphs of the averages. These are shown in Fig. 19. In both sexes of both species, the curves show a high rate of growth in hatchlings which gradually declines to a low rate in old age but there is nothing to indicate that growth completely stops.

For further comparison, the smoothed curves of both snakes were plotted together as shown in Fig. 20. In one of the graphs, the comparison shows the actual increase of length of the two snakes and in the other, the percentage increase in length.

In deriving a smoothed curve from such scattered data, it is obvious that the vertical deviations above and below any selected line must be equal to each other. Because this could be fulfilled by so many lines, a line of best fit was selected, in which the sum of the squares of the vertical deviations from the line represents the minimum obtainable from all the lines. If this method is used on the previous data (when y equals the log base 10 of the increase in inches of length of the next growing season and x equals the length preceding that growing season), the smoothed curves are represented by the following formulae. Rattlesnakes:

male; y equals 1.5014 - .0487x; female; y equals 2.1163 - .0817x.

Striped racers:

male; y equals 1.9364 - .0496x; female; y equals 2.0451 - .0558x.

These formulae indicate differences between the sexes in both species. The pattern shown on the graph shows greater similarity between the same sexes of different species than between different sexes of the same species.

RATTLE GROWTH RELATIONSHIPS

In order to determine the rate at which rattles grow, the records were culled to segregate those cases in which the rattle sets were complete (none lost) and in which the recapture records indicated a lapse of one growing season. From these data, Table 3 was compiled to show the yearly rate at which rattles were added.

The data on hatchlings indicate that they ordinarily molt at the time of birth and lose the fetal button. Those that reach the den without further molting, bear a single black solid loose button but those occasional individuals that bear a black base and a single loose button indicate that an additional molt has occurred. During the next growing season after one winter of hibernation, two molts is the rule and most of them return with a black base, a loose rattle and a loose button (Blb). Those cases which possessed a base and button (Bb) during their first winter, usually return to the den with two rattles in addition to the base and button (B2b). Thereafter, as shown in Table 3, there is an increasing tendency to molt only once per growing season instead of twice and thereby add only one rattle per year.

AGE-RATTLE RELATIONSHIPS

Hatchling rattlesnakes, which were easily recognized, came to the den in the fall bearing a single solid black button, or if they had molted, bearing a black base and a loose button. They emerged without conspicuous change in the spring. There is no difficulty in also recognizing the yearlings that reach the den at the end of the following summer season bearing one rattle in addition to the black base and button. But those yearlings which return to the den bearing two rattles in addition to the base and button cannot be distinguished certainly from the two year olds bearing the same number.

TABLE 1

MALE GREAT BASIN RATTLESNAKE

LENGTH IN INCHES	NUMBER OF CASES	AVERAGE		SMOOTHED	
		INCREASE IN INCHES	% INCREASE	INCREASE IN INCHES	% INCREASE
16	2	8.15	50.90	5.30	33.13
17	5	5.21	29.75	4.70	27.65
19	1	4.60	24.20	3.80	20.00
20	5	2.96	14.80	3.40	17.00
21	3	2.80	13.33	3.00	14.30
22	4	1.87	8.50	2.70	12.27
23	6	1.77	7.69	2.40	10.40
24	12	2.21	9.20	2.10	8.75
25	11	2.02	8.00	1.90	7.60
26	8	1.42	5.57	1.70	6.54
27	13	1.66	6.14	1.50	5.56
28	9	1.49	5.32	1.40	5.00
29	23	1.42	4.89	1.20	4.14
30	15	.87	2.90	1.10	3.67
31	13	.76	2.45	.98	3.16
32	10	.75	2.34	.88	2.75
33	12	.94	2.85	.78	2.67
34	5	.82	2.41	.70	2.06
35	1	.40	1.14	.63	1.80
36	2	.65	1.00	.56	1.56
38	1	.75	2.00	.45	1.18

FEMALE GREAT BASIN RATTLESNAKE

LENGTH IN INCHES	NUMBER OF CASES	AVERAGE		SMOOTHED	
		INCREASE IN INCHES	% INCREASE	INCREASE IN INCHES	% INCREASE
16	3	5.27	32.90	6.30	39.38
17	1	5.30	31.17	5.20	30.58
19	1	4.30	22.60	3.60	18.95
20	5	2.80	14.20	3.00	15.00
21	1	2.80	13.30	2.50	11.90
22	3	2.20	9.90	2.05	9.30
23	9	1.58	6.86	1.70	7.40
24	9	1.63	6.79	1.40	5.80
25	22	.91	3.64	1.15	4.60
26	19	.96	3.69	.96	3.70
27	18	1.50	5.50	.80	2.96
28	12	1.05	3.75	.66	2.36
29	7	.29	1.00	.56	1.93
30	1	.31	1.00	.46	1.53
31	5	.48	1.50	.38	1.22

TABLE 2

MALE WESTERN STRIPED RACER

LENGTH IN INCHES	NUMBER OF CASES	AVERAGE		SMOOTHED	
		INCREASE IN INCHES	% INCREASE	INCREASE IN INCHES	% INCREASE
24	1	6.30	26.3	6.30	26.3
25	1	5.40	21.6	5.60	22.4
27	2	4.25	15.7	4.39	16.3
29	4	4.85	16.7	3.40	11.7
30	4	2.24	7.5	3.00	10.0
31	4	1.69	5.5	2.60	8.3
32	9	1.94	8.7	2.30	7.2
33	8	2.21	6.7	2.00	6.1
34	8	1.31	3.9	1.80	5.3
35	11	1.45	4.1	1.55	4.4
36	11	1.51	4.2	1.39	3.9
37	15	.89	2.4	1.20	3.2
38	14	.91	2.4	1.05	2.8
39	8	1.01	2.6	.92	2.4
40	3	1.16	2.9	.82	2.1
41	2	1.50	3.7	.62	1.8
42	2	.55	1.3	.57	1.4
44	1	.50	1.1	.50	1.1
45	1	.50	1.1	.48	1.0
46	1	.60	1.3	.38	.8

FEMALE WESTERN STRIPED RACER

LENGTH IN INCHES	NUMBER OF CASES	AVERAGE		SMOOTHED	
		INCREASE IN INCHES	% INCREASE	INCREASE IN INCHES	% INCREASE
23	1	4.70	20.4	5.00	21.8
29	2	2.95	10.2	2.60	9.0
30	6	2.80	9.3	2.30	7.7
31	4	2.55	8.2	2.10	6.8
32	5	2.25	7.0	1.85	5.8
33	4	1.60	4.9	1.65	5.0
34	9	1.48	4.4	1.50	4.4
35	9	1.16	3.3	1.35	3.9
36	11	.61	1.7	1.20	3.3
37	6	1.10	3.0	1.19	3.2
38	4	.80	2.1	.98	2.6
39	1	1.00	2.6	.85	2.2
40	3	.60	1.5	.75	1.9

RATTLE-AGE

Table 4 shows the number of rattles borne by snakes of the same ages in selected cases in which the rattles were intact and in which, not only the initial age is known but also the age at successive recaptures. It is obvious that some snakes of the same age have different numbers of rattles. Data from this table were incorporated in Fig. 21 to indicate approximate age of each rattle class. This gives a comparison of growth rate in length and growth rate of rattles.

RATTLE AND LENGTH GROWTH RELATIONSHIPS

Because of the strong negative correlation between length and rate of growth in length, it was suspected that there might be a similar correlation between length and rate of growth in rattle numbers. For this reason, Table 5 was prepared to show average growth in length for each rattle class in all cases in which rattle sets were complete. From Table 5 and other data, Fig. 22 was prepared to show the relationships between rattle classes and average length per rattle class. It seems significant that the curves in this figure are so regular that smoothing was scarcely necessary. It is thus shown that hatchling rattlesnakes molt twice and add two new rattles during the first full growing season but that the percentage of snakes that add two rattles per year declines rapidly within the next few years so that few snakes add more than one each year after they are 3 years of age.

AGE-LENGTH-GROWTH RELATIONSHIPS

Rattlesnakes. For further study of those cases, in which initial age could be determined, tables were prepared to show separately by sexes the age, length and growth as determined by successive recaptures. Many other records treated in preceding sections show growth and elapsed time but in most cases, initial ages could not be accurately determined and were not used in this connection.

From the data here used, Table 6 was prepared to show in summary form for each sex the average and range for both length and growth in length at various ages. These data when plotted on a graph with length against age (Fig. 24) show for each sex the actual average length at successive ages in the first few age classes. A smoothed curve for each sex furnishes a base for predicting the age of rattlesnakes at this den from their lengths.

Striped Racers. Hatchlings of striped racers that enter the den in the fall are easily recognized not only by their size, usually between 14 and 17 inches in length, but also by their appearance. After a winter hibernation, they emerge in the spring with negligible change. Most of the yearlings that enter the den at the end of the following summer season are also easily recognized by size, but thereafter more and more difficulty is encountered in determining age by size. It has been possible, however, to determine age and size from recapture records.

From the length-growth studies, it is obvious that if the lengths of hatchlings, yearlings and 2-year-olds were plotted, there would be a concentration around the mean length of each age with very little overlap between them but beyond these, the overlaps in length between age groups would be so great as to make it difficult, if not impossible, to segregate ages according to length.

All those cases in which initial age could be determined and successive recaptures were available have been studied and a summary of the results is shown in Table 7 from which, it is obvious that snakes increase in length with age but the rate of increase gradually declines during the period shown in the table.

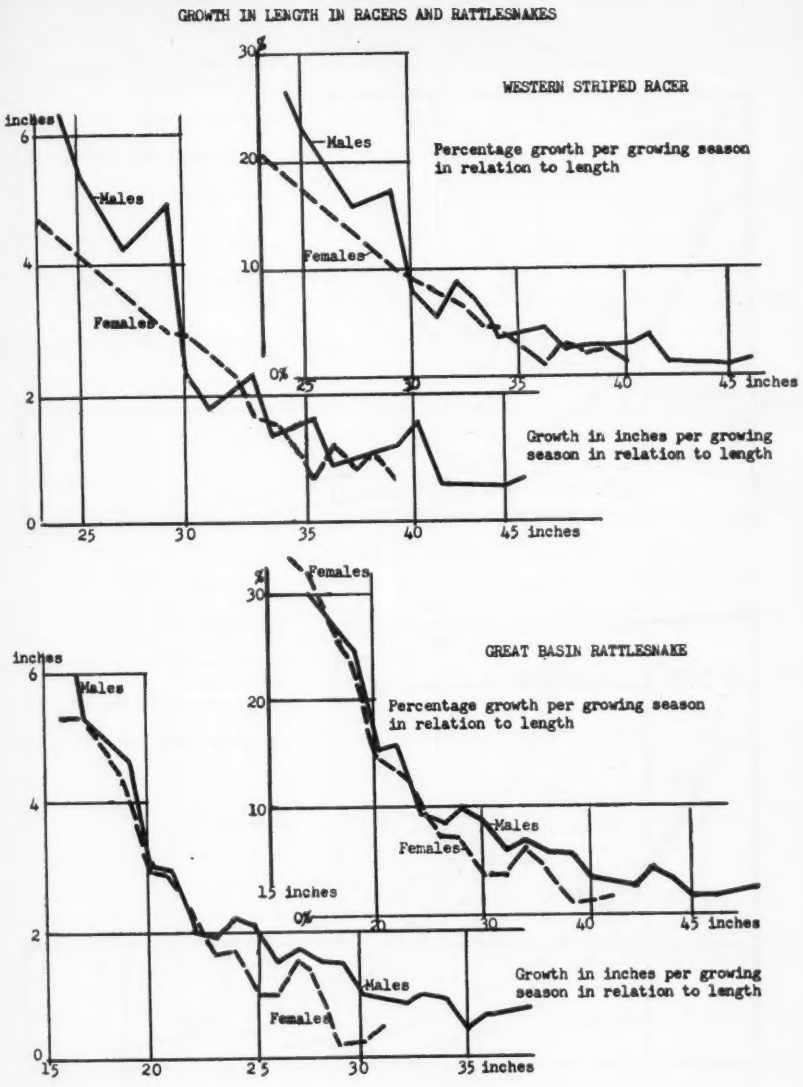

Figure 19. Graphs showing unsmoothed curves of male and female growth in length and growth in percent in rattlesnakes (below) and western striped racers (above).

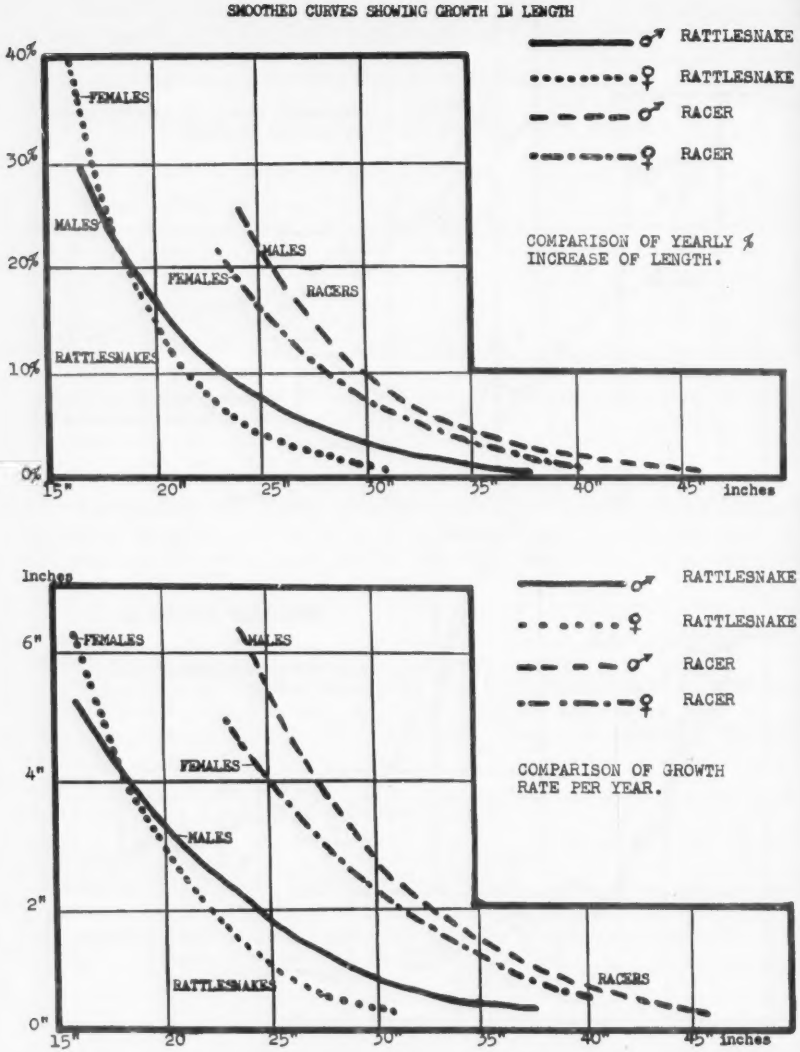

Figure 20. Graphs showing comparison of smoothed curves of male and female growth in length and growth in percent in rattlesnakes and striped racers.

CORRELATION OF RATTLE GROWTH WITH LENGTH GROWTH

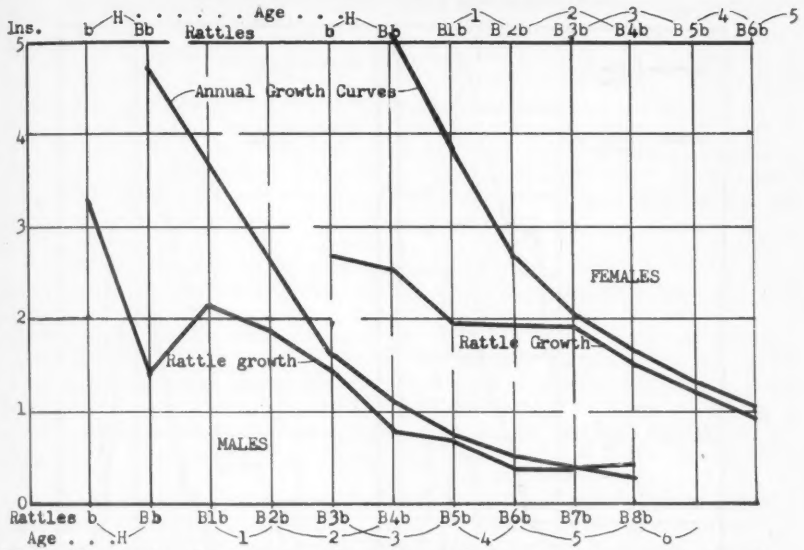

Figure 21. Graphs showing comparison separately by sexes of growth in length per year and per rattle. The divergence in early age indicates addition of 2 rattles per year whereas the coincidence of the two curves in later life indicates addition of but one rattle per year.

CORRELATION OF AGE AND LENGTH IN RATTLESNAKES

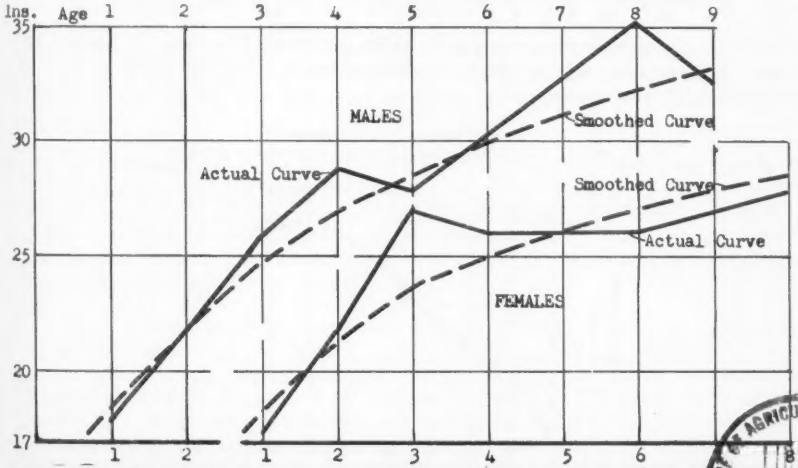

Figure 24. Graphs showing separately by sexes both unsmoothed and smoothed curves of correlation between increasing age and increasing length. The smoothed curves may be used to determine approximate age from the length.

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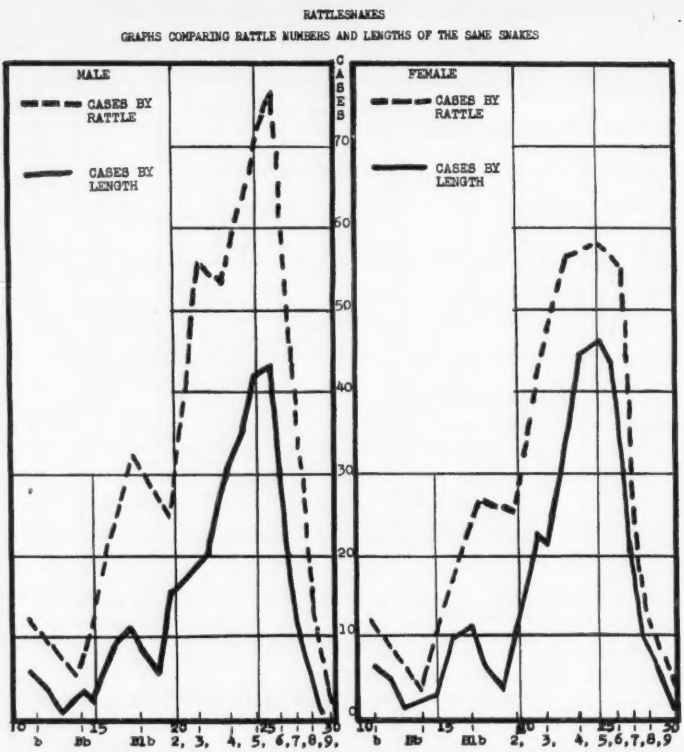

Figure 22. Graphs showing close correlation separetely by sexes the number of snakes tabulated of various length and rattle classes. Note the close parallelism of the curves.

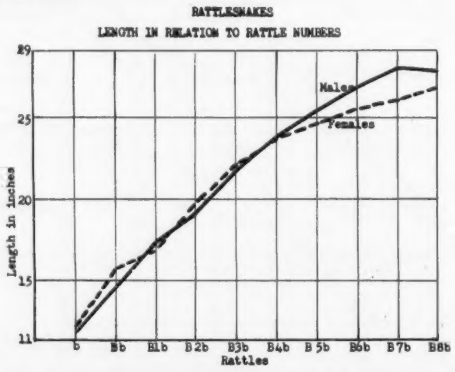

Figure 23. Graph showing separately by sexes how increase in snake length is correlated with increase in rattle numbers.

DISCUSSION

The length-growth tables show that there is a rapid rate of increase in length in small snakes which gradually declines to a very slow rate in the longest snakes. We are led to suspect that if the growth curves were complete, the growth rate of the zygote would begin at zero and rise rapidly through the embryonic and fetal stages during a period lying between two and four months to a maximum about the time of hatching and then decline over many years as shown in the plotted curves. The growth rate of striped racers probably rises to a greater maximum than that of the rattlesnakes. When the average and range of length in the annual classes are known, the length-growth curves can be used to predict the average range of length and growth for the ensuing age group.

The small snakes are no doubt young and the long ones old. To determine the quantitative correlation between age and length in rattlesnakes, the length and growth relationships of the various rattle classes were systematically analyzed. The evidence presented in Table 3 indicates that there is a regular pattern of rattle addition in both sexes. This pattern begins with addition of two rattles during the first regular growing season but thereafter, more and more add only one per season so that after the third growing season, it is seldom that two are added. It is not certain that this relationship carries over into old age since the data are inadequate to show the yearly additions in strings of rattles that are incomplete.

This implies a high degree of correlation between rattle addition and age. Such a correlation was presented in Table 4, and was made possible by cumulative life history records of individually identifiable snakes. It is evident from these data that hatchlings are easily recognizable, that snakes of the B1b rattle class are always one year old and those of the B3b class are two years old, but it is uncertain whether those of the B2b class are one or two years old and those of the B4b class are two or three years old.

Thereafter there is so much overlapping in numbers of rattles borne by snakes of the same age that the number of rattles cannot be used as an absolute criterion of age. Despite this uncertainty, however, a complete set of rattles is useful in obtaining an approximation of age which may be determined by subtracting 2 or 3 from the total number to compensate for the growing seasons in which two rattles are added.

It is uncommon, however, to find more than 6 to 9 rattles on one snake having either a complete or incomplete set. The older rattles get worn by use and fall off as new ones grow. A method is being developed by which the number of rattles that have been lost can be roughly approximated. By adding the number lost to those present and subtracting 2 or 3 as already explained, a very general idea of the snake age can be obtained.

The correlation of rattle numbers with length and growth rate was shown in Table 5 and in Figs. 21, 22 and 23. The parallelism between length growth and rattle growth in the same individuals shown in Fig. 21 indicates a significant correlation between the two. From the configuration of the graph, it is demonstrated that hatchlings and yearlings can ordinarily be segregated by either length or rattle characters. While this graph shows the correlation only in young snakes, it would doubtless be valid in older snakes provided the loss of rattles could be accurately determined.

TABLE 3

ANNUAL INCREASE IN RATTLE NUMBERS

Rattle Class	MALES No. of Cases	Rattles Added one No.	%	two No.	%	FEMALES No. of Cases	Rattles Added one No.	%	two No.	%
Bb	0	0	0.0	0	0.0	2	2	100.0	0	0.0
B1b	12	5	41.7	7	58.3	5	2	40.0	3	60.0
B2b	2	1	50.0	1	50.0	5	2	40.0	3	60.0
B3b	14	9	64.3	5	35.7	14	11	78.6	3	21.4
B4b	7	4	57.0	3	43.0	9	5	55.5	4	44.5
B5b	9	2	22.2	7	77.8	8	7	87.5	1	12.5
B6b	1	1	100.0	0	0.0	7	7	100.0	0	0.0
B7b	5	5	100.0	0	0.0	2	1	50.0	1	50.0
B8b	1	1	100.0	0	0.0	0	0	0.0	0	0.0

TABLE 4

Table of Yearly Rattle Growth Where Initial Age is Known

Age	Male Rattlesnakes No. of Cases	Rattle Range	Female Rattlesnakes No. of Cases	Rattle Range
1	20	All B1b	13	All B1b
2	12	(5) B2b (7) B3b	6	(2) B2b (3) B3b (1) B4b
3	5	(3) B4b (1) B5b (1) B6b		
4	5	(1) B5b (4) B6b	2	(1) B5b (1) B4 + 2b
5	2	(2) B6b	2	(1) B6b (1) B7 + 1b
6	1	(1) B8b		
8			1	(1) B9b

TABLE 7

STRIPED RACERS

Age-Length-Growth Table

Age	Male No. of Cases	Length Ave.	Range	Growth in 1 yr.	2 yrs.	Female No. of Cases	Length Ave.	Range	Growth in 1 yr.	3 yrs.
1	5	24.7	22.8-25.8	6.3	9.9	4	23.1	21.2-24.5	3.9	11.0
2	1	31.1		3.6						
3	2	34.0	31.8-36.2	1.4						
4	1	32.8		1.0		2	35.2	34.8-35.6		
5	1	33.8			2.3					

TABLE 5

LENGTH-GROWTH RELATIONSHIPS BASED ON RATTLE DIFFERENCE

Rattle Class	Male			Female		
	No. of Cases	Average Size	Average Growth to next class	No. of Cases	Average Size	Average Growth to next class
b	12	11.54	2.96	12	11.69	3.94
Bb	5	14.50	2.72	4	15.63	1.42
B1b	32	17.22	2.18	26	17.05	2.69
B2b	24	19.4	2.24	25	19.74	2.32
B3b	55	21.64	2.17	45	22.06	1.70
B4b	53	23.81	1.69	56	23.76	.94
B5b	68	25.50	1.40	58	24.70	.92
B6b	76	26.90	1.04	55	25.62	.58
B7b	42	27.94	.14	17	26.20	.59
B8b	15	27.80		10	26.79	.51
B9b	0	—	—	4	27.30	—

TABLE 6

AGE-LENGTH-GROWTH OF RATTLESNAKES

AGE	MALES					FEMALES				
	No. of Cases	Length Ave.	Length Range	Yearly Growth Ave.	Yearly Growth Range	No. of Cases	Length Ave.	Length Range	Yearly Growth Ave.	Yearly Growth Range
1	20	18.00	16.2–19.6	3.1	1.0–6.0	14	17.7	16.5–19.8	4.3	1.9–6.4
2	4	21.92	19.4–24.7	3.1	1.2–5.0	2	21.8	20.9–22.6	—	— —
3	6	25.80	24.0–28.0	2.9	2.7–3.2	1	27.0	— —	1.0	— —
4	2	28.80	26.7–28.5	.3	— —	2	26.1	25.3–26.8	—	— —
5	2	27.70	25.4–30.0	1.6	1.2–2.1	0	—	— —	—	— —
6	2	30.30	28.5–32.1	.5	— —	1	26.2	— —	—	— —
8	1	35.8	— —	.6	— —	2	28.1	28.0–28.2	.5	— —
9	1	32.8	— —	1.2	— —	0	—	— —	—	— —

Fig. 22 shows an association between length and rattle class in rattlesnakes up to 4 or 5 years of age but the data are insufficient to carry the analysis into old age. This curve is produced between a factor of rattle increase which decreases rapidly at first and then becomes stabilized and a factor of length increase which continues to decline in rate of growth indefinitely. This is an indication that if extended into old age, the curve would tend to level off (approach an asymptote).

The interrelations of rattle class, age, and growth rate are shown in Figure 23. The growth rate for each rattle class declines at an even rate, as is shown by the solid line; but when the growth rate is plotted for each year, as indicated by the broken line, a curve is obtained which closely approximates the length growth curves previously shown.

The section on age, length, and growth relationships was prepared to indicate average length and yearly growth and their variation for each sex of each species separately. In the rattlesnakes there seems to be little overlapping of length range during the first three years, but thereafter it becomes more and more difficult to determine age from length. However, the evidence indicates that beyond three years a good approximation of age can be made if both length and rattles are considered. The variation of growth rate in age classes appears to be great, but most individual cases conformed with the average and only a few are found at the extremes.

The graphs in Fig. 24 show the high degree of correlation between the actual age length groupings and the predicted lengths at given ages as taken from the length growth curves when the yearling length ranges are known.

It appears that the racers show greater growth rates than the rattlesnakes and hence reach greater total lengths in the same time. Does this imply greater cellular growth rate in the racers? Comparative study of weights in the two species are now being made and it is believed that the weight-growth rate of the rattlesnakes will more nearly approximate, if not exceed, that of the racers than do length-growth rates. If so, the difference between the two species would have to be explained on the basis of cellular arrangement rather than cellular growth rate.

REFERENCES

Fitch, Henry S. 1940. A field study of the growth and behavior of the fence lizard. Univerity Calif. Publs. in Zool., 44:151-172.

Goin, Coleman J. and C. C. Goff. 1941. Notes of the growth rate of the gopher turtle, *Gopherus polyphemus*. Herpetologica, 2:66-68.

Klauber, L. M. 1937. A statistical study of the rattlesnake. IV the growth of the rattlesnake. Occ. Papers of San Diego Soc. Nat. History, 3:1-56.

Pope, Clifford H. 1937. Snakes alive. Viking Press, New York City, 238 pp.

Rodgers, Thomas L. and Viola H. Memmler. 1943. Growth in the western bluetailed skink. Trans. San Diego Soc. Nat. History, 10:61-68.

Woodbury, Angus M. and Ross Hardy. 1948. Studies of the desert tortoise, *Gopherus agassizii*. Ecol. Monographs, 18:145-200.

COLOR ANALYSIS IN THE GREAT BASIN RATTLESNAKE

Earl W. Smart

INTRODUCTION

Because there were so many variations in the colors and patterns in the rattlesnake of the winter populations of the den, near Grantsville, Tooele County, Utah, an attempt was made to analyze the variations in the color pattern. The study revealed differences of two types—those which took place in individuals with increasing age and those which arose from differences in color between different adults. The former are concurrent with changes in a life history; the latter result from divergences during the life history of different individuals.

Since colors of the abdomens are very similar, the variations are confined mainly to the dorsal colors and patterns which usually consist of a unicolored background with contrasting blotches. The general impression of the background color is that most of the adults were light brownish-gray that matched the desert soil of their habitat but there was a noticeable sprinkling of yellowish snakes similar to those of the Colorado Basin in eastern Utah, pinkish like those of the Navajo country, greenish like those of the Great Plains and melanistic like those of the Pacific Coast.

The snakes were measured qualitatively and quantitatively for color on the abdomen, dorsum, and blotches by the use of Maerz and Paul's *Dictionary of Color*. The qualitative measurements were made in the laboratory under a set of stable light conditions by comparing a part of the snake's body with the various colors shown in the dictionary. After these colors were determined qualitatively they were then calculated quantitavely from the arrangement of the colors in the dictionary in which the white of the page was considered as zero, the deepest color given as one hundred and the various shades graded in percentage between the two extremes. On any given page in the dictionary the shades of color are represented across the page by capital letters, ranging from A to L, each of which indicates a vertical column of a given shade beginning with the page white (A) and increasing by the addition of one shade in each successive column until the full color (100 per cent) is realized at L. The figures 1 to 12 running down the side of the page represent horizontal columns which likewise begin with page white (1) and add successively one shade of the complementary color used on the same page until the full color (100 per cent) is reached at 12.

Each series of two colors extends over 8 pages. The first page contains only the 2 colors and their combinations made by overlapping of the vertical and horizontal columns. To each successive page is applied one additional shade of gray until the maximum gray (100 per cent) is reached on the eighth page where it almost obliterates the shades of the other colors on the page. These are not accurate percentages of the color itself, but only approximate percentages as represented by the shades given in the dictionary. These relationships are shown in Table 1.

The quantitative measurements were tabulated to show the range in percentage of color found in each portion of the snakes measured. A summary of these tabulations is shown in Table 2 and graphs showing such relationships are given in Figure 25.

TABLE 1

Yellow	A	B	C	D	E	F	G	H	I	J	K	L
	0	9	18	27	36	45	54	63	72	81	90	100%
Orange	1	2	3	4	5	6	7	8	9	10	11	12

Gray	1	2	3	4	5	6	7	8
	0	14.3	28.6	42.9	57.1.	71.4	85.7	100%

TABLE 2

AVERAGE PERCENT OF COLOR

Abdominal Color			Dorsal Color			Blotch: Center			Blotch: Outer Border		
Gray	Yellow	Orange	Gray	Yellow	Orange	Gray	Yellow	Orange	Gray	Yellow	Orange
Hatchlings from the Grantsville Den											
42.9	29.4	6.7	44.8	8.8	11.3	85.7	25.8	48.1	14.3	9.0	0.0
Juveniles from the Grantsville Den											
33.4	34.0	9.2	57.7	9.1	23.9	83.6	15.5	43.3	16.1	3.4	0.2
Spring Adult Males from Grantsville Den											
28.7	40.8	10.6	58.5	16.1	23.6	71.8	17.2	31.2	1.2	0.5	0.3
Fall Adult Males from Grantsville Den											
29.6	24.4	10.4	59.3	12.1	23.4	72.4	17.6	31.7	2.2	1.4	1.2
Spring Adult Females from Grantsville Den											
28.9	37.6	12.6	57.1	13.8	26.8	75.6	17.6	37.4	5.1	1.8	0.6
Fall Adult Females from Grantsville Den											
30.1	21.9	12.9	60.2	5.5	24.3	76.8	17.8	36.9	2.7	1.7	1.7
Adults from Kaysville Den											
34.3	54.0	14.4	62.8	37.8	30.6						

TRENDS IN COLOR CHANGE

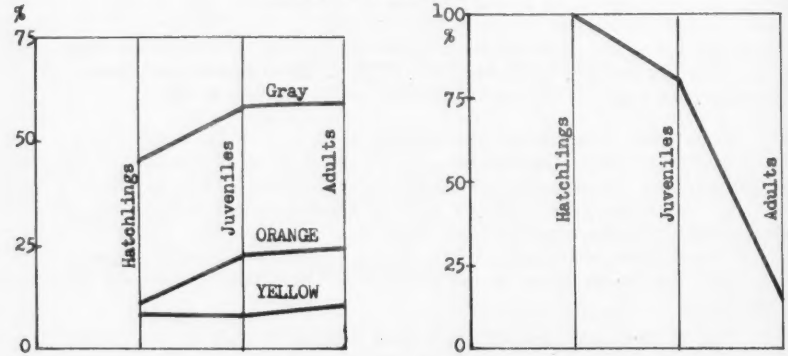

Figure 25. Graphs showing (left) color changes in dorsal background and (right) presence of outer ring in dorsal blotch in hatchlings, juveniles and adults.

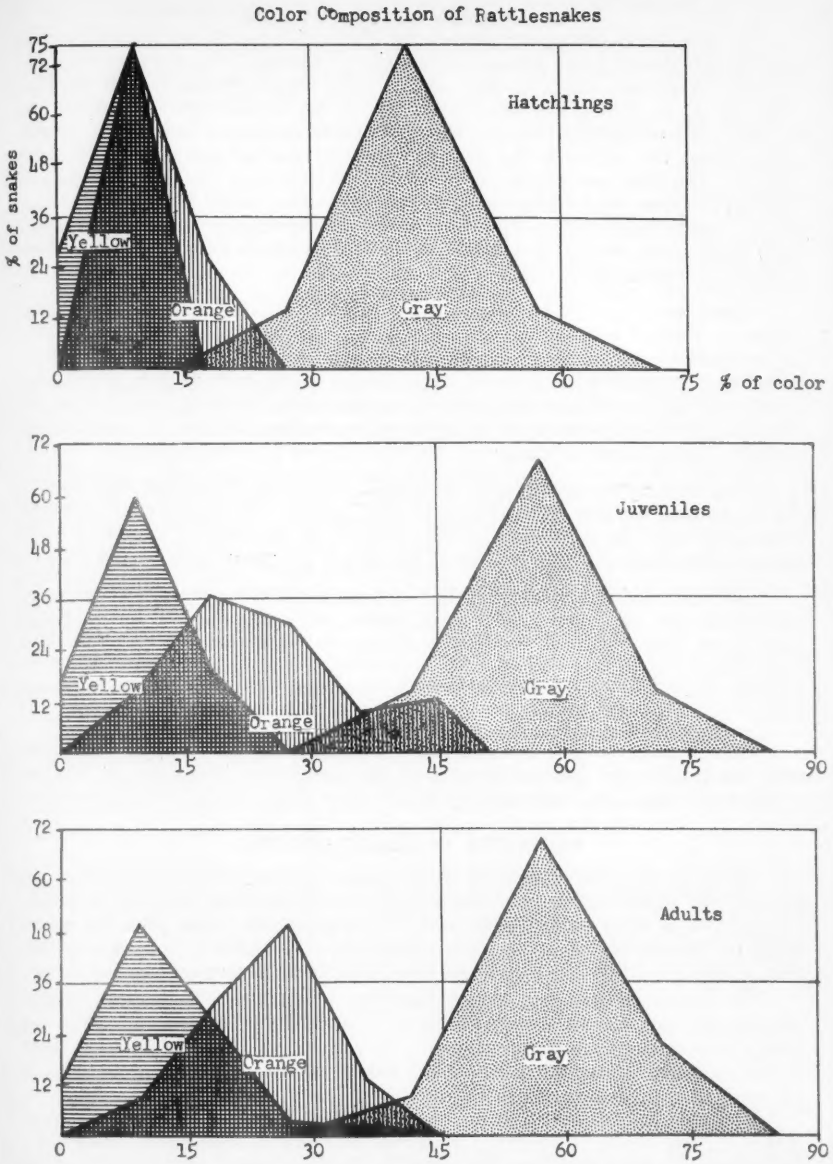

Figure 26. Graphs showing color composition of the dorsal background in hatchlings (top), juveniles (middle) and adults (bottom) in which % of snakes is plotted against % of yellow, orange and gray.

CHANGES IN COLOR PATTERN

It was found during the studies that the hatchlings always possessed clear and distinct dorsal color patterns, consisting of blotches in a more or less unicolored background. Parts of this distinct color pattern gradually dim with increasing age or become lost and modify the pattern in older age. The major part of these changes appears to occur during the onset of sexual maturity at 3 or 4 years of age but ordinarily the changes appear to continue more slowly throughout life. The clear and distinct color pattern of hatchlings includes a single row of large blotches along the back and 3 rows of smaller partial blotches along each side. A dorsal blotch is usually composed of a light narrow outer border and a dark inner border enclosing a lighter central patch that is usually slightly grayer than the unicolored background outside the blotches.

Color analysis of 8 hatchlings, 47 juveniles and 272 adults from the den, shown in Table 2 and Figs. 25 and 26 indicates that hatchlings ordinarily have a lighter dorsal background color than older snakes. It appears from the measurements that juveniles possess about one dictionary shade each of gray and orange more than the hatchlings and adults about one more shade of yellow than the juveniles. This may represent a trend of increasing density of color which probably begins before hatching and continues at least to sexual maturity.

The blotches are also affected by changes in coloring which not only modify the appearance but also cause changes in the pattern. The major change results from invasion of the light outer border of the dorsal blotches by the dorsal background color, thus reducing the size of the blotch by removing the outer ring.

Also the dark inner border which is very narrow in hatchlings, gradually spreads inward and encroaches on the lighter central patch. On the posterior part of the body, this often completely obliterates the center and many of them form dark cross bars similar to those on the tail. Anteriorly, this seldom occurs and the blotches usually consist of irregular wide dark borders with light centers similar to the dorsal background.

The small lateral blotches also tend to fade with age. The upper and lower rows are usually the first to blend with the background and later in life the middle row fades. The mechanism by which these changes occur was not studied.

VARIATION IN ADULT COLORS

In analyzing adult coloration, it was found that the colors exhibited in all parts of the snake body were composed of various combinations of red, yellow and gray, or as analyzed in the dictionary of orange, yellow and gray. By calculating the proportions of each, it was found that yellow varied from 0 to 63 per cent, orange from 0 to 54 percent and gray from 15 to 86 per cent.

By comparing abdomen, dorsal background and blotch, it became evident that the abdomen contained proportionately much more yellow and less gray and orange than most of the dorsal colors. In fact, there was little variation in color of the abdomens. By contrast, the dorsal colors varied a great deal, not only in different individuals but also in different portions of the pattern.

The dorsal background color which becomes more conspicuous in older snakes and appears to be the major factor in their general appearance, has a great deal of gray in it but less than that found in the dark border of the blotch which encroaches on the center. Of 272 adults tabulated, 77 per cent were regarded as light brownish-gray, 15 per cent darker colored, 5 per cent yellowish, 2 per cent had a greenish tinge and 1 per cent a pinkish or reddish tinge.

COMPARISON WITH ENVIRONMENTAL BACKGROUND

The habitat in which these snakes live is a desert which supports a sparse stand of sagebrush, usually one to two feet in height, or other low bushes such as shadscale, intermixed with forbs and grasses. In some of the surroundng areas where the bushes have been artificially removed for cultivation, cheat grass, a new comer to the area, is very common.

During most of the summer, when snakes are abroad on the range, there is little vegetation growing between the bushes and perhaps 60 to 80 per cent of the ground is exposed without any cover that would hide the snakes. It may be inferred from this that snakes moving from bush to bush would be exposed without cover a good deal of the time, although it is presumed that they would seek shelter from weather and enemies in the bushes.

It is well known that desert vegetation is usually gray and the sagebrush and shadscale offer no exception to the rule. In order to study the obvious correlation between snake dorsal coloration and environment, the vegetation and soil colors were also analyzed by the same method with the color dictionary.

It was found that the soils had no yellow in them but had various combinations of gray and orange which gave them a brownish gray appearance. Exposed soil showed 18 to 27 per cent orange and about 57 per cent gray whereas the soil under the vegetation where there was more humus was much darker with about 36 per cent orange and 85 per cent gray. The vegetation itself, although predominantly gray, varied from plain gray through various combinations of gray, yellow and orange.

It thus appears from comparison of soil, vegetation and snake colors, that there is a very high degree of correlation between the three. Snakes with light brownish gray background color have almost the identical color composition of the exposed soil. Many of the brownish gray snakes, however, have some yellow as shown in Fig. 26 but in most of them, the presence of yellow makes little contrast with the soil. The few variants in the population showing yellow, greenish, pinkish or darker colors make more definite contrasts with the soil as all but the dark ones do with the shadows under the vegetation.

For comparison with this study from the Grantsville den, 20 snakes from another den east of Kaysville in the Wasatch Mountains about 45 miles away were also studied by the same method with the color dictionary. The habitat in which these snakes live includes much denser stands of green vegetation that leave much less exposed soil between the bushes. Color analysis of these snakes showed that 16, or 80 per cent of the samples, had the greenish tinge that only 2 per cent of the Grantsville den snakes exhibited.

DISCUSSION

It thus appears that the great majority of the rattlesnakes at the Grantsville den develop in maturity a dorsal background color that very closely resembles the color of the exposed soil of their habitat. This appears to be a gradual development from a hatchling pattern that exhibits much more contrast with the soil. The small percentage of variants in the adults showing contrast with the soil are a very small minority.

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In contrast, the small sample from the Wasatch Mountains where the habitat contains much more green vegetation, indicates that the great majority have a greenish tinge that more closely resembles the vegetative cover than the soil. It may be inferred from these two cases in which the matching colors are very similar, that color changes during life in the majority of individuals lead toward better matching of their dorsal colors with the major colors of their habitats. In one case, it is soil where much of it is exposed; in the other case, it is vegetation where more of the soil is covered.

This yields evidence that supports the idea of natural selection, in which there is a culling of those that do not match their background in favor of those that do match it. The problem of what directs this culling has not been investigated and it cannot be safely prognosticated whether it is due to the action of predators or factors of the physical environment such as sunshine. The mechanism by which the color changes take place has also not been investigated. How they are related to chromatophores and the balance between melanophores and lipophores are problems still unsolved.

REFERENCES

Benson, Seth B. 1933. Concealing coloration among some desert rodents of the southwestern United States. Univ. Calif. Press, Berkeley, Calif. 69 pp.

Dice, Lee R. 1932. Variation in a geographic race of the deer-mouse, *Peromyscus maniculatus bairdii*. Occ. Pap. Mus. of Zool. Univ. Mich., Ann Arbor, Mich.

Maerz, A. and M. Rea Paul. 1930. Color dictionary, McGraw Hill, N. Y., 207 pp., 56 color pls.

Norman, J. R. 1949. A history of fishes. A. A. Wyn. Inc., New York, 461 pp. Chapter on coloration.

Parker, George Howard. 1948. Animal colour changes and their neurohumours. Cambridge Univ. Press, England, 377 pp.

Rahn, H. 1940. The pituitary regulation of melanophores in the rattlesnake. Anat. Rec. 78:supplement 138-149.

1941. The pituitary regulation of melanophores in the rattlesnake. Biol. Bull. Woods Hole, 80:228-237.

Sumner F. B. 1932. Genetic, distributional and evolutionary studies of the subspecies of deer-mouse (Peromyscus). Bibliographia Genetica, 9:21-25, The Hague.

Woodbury, Angus M. and Dixon M. Woodbury. 1944. Notes on Mexican snakes from Oaxaca. Jour. Wash. Academy Sci. 34:360-361. No. 11.

EFFECT OF VENOM INJECTIONS IN RATTLESNAKES

Raymond T. Sanders

During the course of the ten-year study of the snake den, near Grantsville, Tooele County, Utah, it had been noted that an occasional rattlesnake died under conditions that aroused the suspicion of poisoning from snake bite. This study was undertaken to determine the approximate dosage of venom required to produce lethal results in rattlesnakes. The snakes used throughout the experiments were of the species *Crotalus viridis lutosus*. The venom was collected from snakes of this species. It was also desired to determine as nearly as possible the intraspecific systemic effects of the venom. During the course of these experiments 26 snakes were injected, of which twenty-one died. Fifteen of these were examined both macroscopically and microscopically, and 278 slides of normal and abnormal tissues were studied.

Specimens were collected for use by trapping at winter den sites near Grantsville, in Tintic Canyon, and in Emigration Canyon, Utah, through the month of September 1949, as the snakes were entering the dens. Throughout the experiments specimens were handled by employing a slipstick with a leather loop in which their heads were held.

To assure relative standardization of potency of the poison, venom was collected only from the larger snakes that did not display the juvenile pattern, and were usually more than 20 inches in length. Venom was collected into small glass vials by catching the fangs of the snake over the edge of the vial and massaging the glands forward with the thumb and forefinger. To minimize the effects of deterioration of the venom, it was collected immediately before injection, thus precluding any need for storing or drying.

Throughout the experiments, fresh venom was used exclusively in preference to dried venom, since it was desired to determine the probable effects of intraspecific snakebite in nature. The venom from as many snakes as were available was pooled at milking in order to minimize the variations that might be expected between the venoms of various individuals.

The venom collected was then injected into as many snakes as the supply would allow. The dosages given were calculated in proportion to the body weights. Injections were made with a one cc tuberculin syringe graduated to 1/100 cc, about four or five inches posterior to the head in the longissimus muscle of the right side. Care was exercised not to penetrate the body cavity, but to keep the needle in the muscle. The animals were caged separately to prevent infliction of additional wounds.

Routine methods of autopsy were employed. An incision was made the full length of the snake along the left costal margin and the head removed and preserved. The skin was removed the entire length, care being taken not to disturb the histolyzed tissues at the site of the injection. The lengh of the hemorrhagic area around the injection was measured. Beginning with the head and working posteriorly, each of the vital organs was examined and conditions were noted. After gross examination, a sample was taken of each organ for future study. These were fixed either by means of Bouin's fluid or 10 per cent formalin. Slides were made of the bloody fluids found in any of the tissues or organs that indi-

cated hemorrhage. Normal tissues were taken from an uninjected snake for comparison. The tissues were run through conventional methods of dehydration, employing a series of steps from 35 per cent to absolute alcohol, clearing in xylol and embedding in paraffin. Sections were cut and mounted, using standard techniques, and stained in Harris' hematoxylin and eosin.

Dosages were administered in fractions of a ml per 10 gms of body weight, in an effort to reach the minimum lethal dose. In the first experiments a series of eleven snakes were injected with doses varying between 0.1 and 0.025 ml per 10 grams body weight. Three specimens receiving the smaller dosage survived, indicating the minimum lethal dose lay between 0.025 and 0.05 ml per 10 gms body weight. The remainder of the injections were between 0.05 and 0.025 ml per 10 gms body weight. A dosage of 0.04 ml proved lethal, but one specimen receiving 0.035 ml survived. Although this data is not sufficient to prove 0.04 ml is a minimum lethal dose, it does indicate the range is between 0.04 ml and 0.025 ml per 10 gms body weight, possibly approaching 0.035 ml.

Difficulty was experienced in getting the specimen immediately after death. The majority died during the night, and with considerable variance in longevity. Four of the 26 specimens injected were autopsied immediately after death. Of the others, only eleven which were in suitable condition were autopsied, making a total of 15 snakes.

Gross examination of the specimen revealed edema along the *M. longissimus* for approximately 12 cm on the average, radiating laterally. In a few instances there was evidence of oral hemorrhage. On palpation, the swelling felt spongy, and the integument seemed loose from the underlying muscle. Occasionally the superficial corneum would slough, but never the integument with underlying affected muscles.

The skinned animal was examined grossly for hemorrhagic areas, and these noted. The extent of hemorrhage along the *M. longissimus* was measured, and the amount of lateral radiation noted. In only one specimen was there any evidence of bleeding into the mesenteries, and this was confined to one or two isolated blotches 2 to 3 mm in diameter in the greater omentum. In every case there was some involvement of the *M. semispinalis et spinalis,* and considerable involvement of the *M. retractor costae biceps.* This was, however, restricted to the right side. The anterior thoracic region was filled with bloody fluid in several cases, and partial coagulation was found in a few instances. The ovaries of specimen 10 were filled with bloody fluid. In each specimen the organs were examined for any abnormalities, most of which were found to occur in the anterior part of the thorax. Although the tracheal lungs appeared in most cases to be hemorrhagic, on sectioning, the lumen was found to be free of any fluid. In three specimens (numbers 6, 11 and 25) a bloody mucous material oozed out when he tissue was cut. In another (18), however, the lumen contained coagulated blood. In each instance only the anterior alveolated portion of the lung was involved; the membranous air sac appeared normal.

The digestive tract was even less involved. In two cases, the esophagus contained bloody fluid (6 and 14); and in another instance (4) the stomach was filled with foamy blood. Otherwise the system, including the liver and pancreas, appeared normal. The bile was a dark green, apparently free of blood.

In one case the heart was found empty, and in another the blood was clotted. All of the other hearts examined contained liquid blood. The macroscopic appearance of the heart was not unusual. The veins and arteries did not lend themselves to macroscopic examination.

The gonads and kidneys were examined together. Nothing unusual was noticed about the testes; however, the ovary of specimen 20 contained small eggs on which there appeared to be bloody blotches. The kidneys of specimen 18 appeared dark and oozed bloody fluid when sectioned.

The greatest abnormality was found in the muscle tissue around the injection. Maceration was so complete that it was possible to pick the *M. longissimus* up in forceps at either margin of the necrotic area and remove it intact. In some instances, clotted blood was observed under the excised muscle, which oozed serous fluid when severed.

Although relatively few organs demonstrated macroscopic pathological conditions, each organ was sectioned, fixed, and prepared for microscopic examination in comparison with similar slides made from a snake that had not been injected.

Microscopically, the only pathological conditions observed were in the histolyzed muscle tissue and lung tissue in those specimens that macroscopically indicated pathology. The spleen, the only part of the lymphatic system examined, appeared normal microscopically.

The lungs of snakes differed pathologically in two ways. In certain of the specimens, the capillaries of the alveolar walls were intact, but partly or totally collapsed and devoid of erythrocytes. There were, however, numerous red blood cells and some cellular debris in the alveolar ducts, without a noticeable increase in number of lymphocytes. In other cases, the capillaries of the alveolae were dilated and filled with blood. Both conditions described are different from the state of normal lung tissue in which capillaries contain erythrocytes without apparent dilation and the alveolar ducts are free of debris.

The condition in the muscle was more consistent. There was apparent hemorrhage into the perimysium, the connective tisue surrounding the striated muscle bundles (fasciculi). In these interfascicular spaces, the number of lymphocytes increased appreciably in proportion to erythrocytes in the perimysium where the damage had been greatest. Red blood cells in these connective tissue spaces did not present a consistent picture. There were clumps of cells that had granular cytoplasm, clumps of rounded red blood cells, and still others (the majority) that appeared quite normal.

Smears were made of the bloody material in the peritoneal cavity, the ovary, and the hepatic vein, and stained with Wright's stain. There was a noticeable difference between those taken from the injected snakes and the normal cells. The cytoplasm of normal erythrocytes stained light blue, whereas that of the experimental animals stained pink. The shape of the abnormal cells was not always consistent, some of them having a bump at one side. The general shape was maintained in most cases. An occasional red blood cell was seen in an obvious state of disintegration. Cellular debris was also present in the abnormal slides. Both of these conditions are indicative of hemolysis. Measurements were taken of the affected cells and compared with the normal. A difference of about 5 microns in length and 3 microns in width was noted, which is approximately 30 per cent increase in size.

After considering these data, it seems probable that the amount of venom required to kill adult snakes is greater than the amount the average snake of this subspecies produces. Of 32 snakes milked on one day, a volume of 3.8 ml of venom was obtained. This is an average volume of 0.118 ml of venom per snake. If 200 gms is taken as an average weight of an adult snake, and a known lethal dose of 0.04 ml per 10 gms body weight is considered necessary to kill, it becomes ap-

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APPENDIX

TABLE 1

Data of Snake Specimens

Spec. No	Weight (grams)	Dose (ml/10g body weight)	Total Dose	Result	Time (hours)
1	120	0.1	1.2	died	24
2	190	0.1	1.9	died	24.5
3	155	0.06	1.0	died	48
4	250	0.05	1.25	died	22
5	310	0.05	1.55	died	22
6	120	0.05	0.6	died	48.5
7	190	0.025	0.48	lived	
8	350	0.025	0.88	lived	
9	50	0.025	0.12	lived	
10	310	0.075	2.3	died	
11	205	0.075	1.5	died	29.5
12	98.5	0.045	0.45	lived	
13	212.5	0.045	0.95	died	64
14	209	0.045	0.94	died	40
15	204	0.05	1.0	died	
16	46	0.05	0.23	died	
17	29	0.04	0.12	died	
18	87	0.05	0.44	died	27.
19	38	0.05	0.19	died	
20	108	0.05	0.54	died	
21	52	0.05	0.26	died	
22	131	0.045	0.59	died	22
23	66	0.045	0.30	died	22
24	100	0.040	0.40	died	22
25	48	0.04	0.19	died	46
26	30	0.035	0.10	lived	

TABLE 2

Source of blood	Size of cell in microns		Size of nucleus in microns	
Normal cells	Length	Width	Length	Width
Bleeding an uninjected, decapitated snake	12.5 x 8.73		6.24 x 3.12	
	15.6 x 10.0		6.24 x 3.12	
	15.6 x 9.35		6.24 x 3.12	
	14.0 x 9.35		5.6 x 3.12	
	13.1 x 9.35		6.85 x 3.12	
	15.6 x 9.35		7.8 x 3.12	
	15.0 x 11.2		9.35 x 3.12	
	15.0 x 9.35		7.17 x 3.12	
Abnormal cells				
Peritoneal cavity	18.7 x 12.1		6.2 x 3.12	
	21.1 x 12.1		9.35 x 3.12	
	16.1 x 12.1		5.6 x 3.12	
Esophagus	17.5 x 12.1		6.85 x 3.43	
	18.7 x 12.1		6.2 x 4.05	
	18.7 x 12.1		6.2 x 4.05	
	18.7 x 12.1		6.2 x 4.05	
	18.7 x 18.7		6.55 x 5.6	
Hepatic vein	16.2 x 12.1		6.85 x 3.74	
	16.8 x 11.2		4.68 x 4.37	
	18.7 x 12.1		6.85 x 4.05	
	16.2 x 10.8		6.2 x 3.74	
	15.6 x 10.8		6.85 x 3.12	
	15.6 x 9.66		6.2 x 3.74	
	15.6 x 10.85		4.68 x 6.2	

15.6 x 10.85 4.68 x 6.2

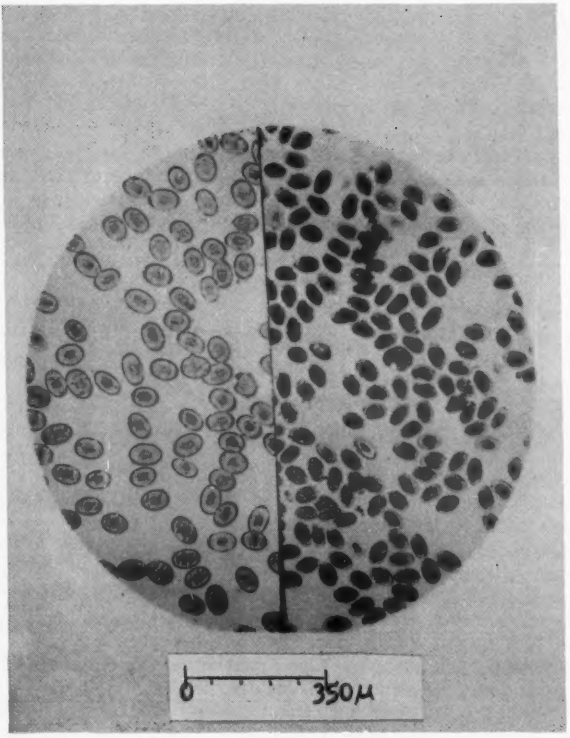

Figure 27. Microphotograph of red blood cells showing normal cells (right) and cells enlarged by the effect of venom (left).

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parent that the average snake does not have sufficient venom to kill a snake of comparable size. However, it is entirely possible that an old adult of 400 gms could inject sufficient quantity of venom into a smaller snake to kill it.

During the course of this study, three factors possibly contributing to the lethal effect of the poison were observed.

One, the loss of blood tissue from circulation into the tissue spaces reduces the efficiency of this system. This condition could conceivably cause a fall in blood pressure, as Essex and Markowiz (1930:329-334) demonstrated in mammals.

Two, the effect of the poison upon the cellular portion of the blood, particularly the red blood cells, would very likely disturb their normal function and perhaps destroy it. The possible clumping of these cells would further reduce their efficiency.

Three, the extensive necrosis around the site of the injection would certainly contribute to the lethal results, but to what extent is hard to ascertain. It would appear that an unmeasured amount of necrosis can be tolerated, since a sufficiently small dose of the poison does not produce lethal results.

REFERENCES

Allen, Ross and E. Maier. 1941. Extraction and processing of snake venom. Copeia, 1941:248.

Amaral, Afranio do. 1937. Bites, snake. F. A. Davis Co., Cyclopedia of Medicine, 2:416-427.

Essex and Markowitz. 1930. Physiological effects of rattlesnake venom (crotalin). Am. Jour. of Phys., 92:329-334.

Gloyd, Howard K. 1946. Case of intraspecific poisoning in the Great Basin rattlesnake. Chicago Acad. of Arts and Sci., Nat. Hist. Msicellanea, 3:1-3.

Keegan, Hugh and Ted F. Andrews. 1942. Effects of crotalid venom on North American snakes. Copeia, 1942:251.

Kendall, James I. 1947. Microscopic Anatomy of vertebrates. Lea and Febiger, Philadelphia, 329 pp.

Lawrence, Barbara. 1945. Brief comparison of short tailed shrew and reptile poisons. Jour. Mam., 26:393-396.

Maximow, Alexander A. and W. Bloom. 1948. A textbook of histology. W. B. Saunders Co., Philadelphia, 661 pp., illustr.

Mitchell, S. Wier. 1860. Researches upon the venom of the rattlesnake. Smithsonian Contrib. to Knowledge, 12:1-149.

Mosauer, Walter. 1935. The myology of the trunk region of snakes and its significance to Ophidian taxonomy and phylogeny. Pub. of Univ. of Calif. at Los Angeles in Biol. Sc. 1:81.

Nichol, A. A., Volney Douglas and Llewellyn Peck. 1933. On the immunity of rattlesnakes to their venom. Copeia, 1933:211.

Rosenfeld, Samuel and Sanford Glass. 1940. The inhibiting effect of snake bloods upon the hemorrhagic action of viper venoms on mice. Am. Jour. of Med. Sc., 199:482.

Tyler, Albert. 1946. On natural auto-antibodies as evidenced by antivenin in serum and liver extract of Gila monster. Proc. of Nat. Acad. of Sc., 32:195-201.

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